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APPROXIMATE NONLINEAR ANALYSIS OF SOLID ROCKET MOTORS AND T-BURNERS

FINAL REPORT

VOL II

GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF AEROSPACE ENGINEERING
ATLANTA, GEORGIA 30332

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JULY 1977

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AIR FORCE ROCKET PROPULSION LABORATORY
DIRECTOR OF SCIENCE AND TECHNOLOGY
AIR FORCE SYSTEMS COMMAND
EDWARDS AFB, CALIFORNIA 93523

FOREWORD

The present report consists of two volumes which describe an approximate nonlinear analysis of solid rocket motors and T-burners and the associated computer programs. Volume I contains the analytical basis for the computer programs and the results of the parametric studies, while Volume II describes the computer programs and serves as a user's manual.

The investigation is entitled APPROXIMATE NONLINEAR ANALYSIS OF SOLID ROCKET MOTORS AND T-BURNERS. The two volumes are additionally subtitled as follows:

Volume I - Analysis and Results

Volume II - Computer Program User's Manual

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Volume II of this report is a user's manual for the computer programs based on the approximate and "exact" nonlinear axial-mode combustion instability analyses developed in Volume I. This volume contains a description of all the main programs and subroutines used in these instability programs, as well as descriptions of the inputs needed to operate the programs and the outputs generated. Sample cases are given to facilitate checkout of the programs. The FORTRAN IV source code for each of the programs is also given.

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TABLE OF CONTENTS

Table of Contents (cont'd)

Table of Contents (cont'd)

1. INTRODUCTION

Volume II of this report is a user's manual for the computer programs based on the approximate and "exact" nonlinear axial-mode combustion instability analyses developed in Volume I. Three approximate programs were developed as follows: (1) nonlinear analysis of solid rocket motors by the Galerkin method, (2) nonlinear analysis of solid rocket motors by the Method of Averaging (MOA), and (3) nonlinear analysis of T-burners (Galerkin method). These programs numerically solve the systems of nonlinear ordinary differential equations which arise on the application of the Galerkin method or MOA to the governing one-dimensional, two-phase partial differential equations. The details of the approximate and "exact" instability models upon which these programs are based are available in Volume I of this report.

This volume contains a description of all the main programs and subroutines used in the instability programs. Descriptions of the inputs needed to operate the programs and the outputs generated are given. Furthermore a sample case is presented to illustrate the text and to facilitate checkout of the program. The entire program has been written in the FORTRAN IV programming language. While the programs have been checked out on a CDC CYBER 70/74-28 system operating under NOS 1.1 at the Georgia Institute of Technology, the structure of the programs has been kept simple enough to be run on any modern digital computer. The program includes an option to obtain plots using a CALCOMP plotter, but the absence of a plotting capability in a computing system does not affect the functioning of the rest of the program.

2. GENERAL STRUCTURE OF APPROXIMATE PROGRAMS

The computations for the solid rocket motor and the T-burner are performed by two separate sets of programs. Programs SOLID1 and SOLID2 compute instability in a solid rocket motor whereas programs TB1 and TB2 refer to the T-burner. Both these sets of programs use the Galerkin method which is described in Volume I. Programs SOLID1 and TB1 compute the coefficients which appear in the differential equations that govern the mode-amplitude functions for a solid rocket motor and a T-burner respectively. The coefficients generated by these programs must be supplied as input to SOLID2 and TB2. Using these coefficients, SOLID2 and TB2 integrate the system of ordinary differential equations for the mode amplitudes in a solid rocket motor and a T-burner respectively. An option is provided for SOLID1 and TB1 to write the generated coefficients onto a disk from which these coefficients can be conveniently recovered by SOLID2 and TB2. The advantage of dividing the computations into two separate programs will become obvious in the program description which follows. With this segmentation of tasks, coefficients can be generated just once using SOLID1(or TB1) and can then be repeatedly run with different combustion responses and different initial conditions as desired using SOLID2 (or TB2), thereby considerably reducing the computer time.

The above two sets of programs utilize the Galerkin method without application of the method of averaging to the resulting mode-amplitude equations. Programs MA1 and MA2 obtain numerical solutions of the equations derived by application of the method of averaging after using the Galerkin method as described in Volume I to calculate the stability behavior of solid rocket motors. Program MA1 corresponds to programs SOLID1 and TB1 since it computes the coefficients appearing in the governing equations. Program MA2 performs the numerical integration of the system of differential equations like SOLID2 and TB2.

Section 3 gives a description of the programs used to investigate the stability of solid rocket motors. The various subroutines, inputs, and outputs are described, and a sample case is presented for each program. Section 4 presents a similar description for the T-burner programs. Equations and appendices referenced in these sections refer to equations and appendices in Volume I.

3. PROGRAMS FOR SOLID ROCKET MOTORS

As pointed out earlier, the motor stability computations are performed by SOLID1 and SOLID2 or MA1 and MA2. These programs are described in the following sections.

3.1 PROGRAM SOLID1

Program SOLID1 calculates the coefficients of both the linear and nonlinear terms which appear in Equations (22) and (23). The coefficients to be calculated are functions of various integrals of complex hyperbolic functions as defined in Appendix C.

Program Structure. The program can be divided functionally into five major sections: (1) input, (2) calculation of the complex linear coefficients, (3) calculation of the complex nonlinear coefficients, (4) obtaining coefficients of the equivalent uncoupled real system, and (5) output.

The inputs to the program include the parameters describing the motor geometry and the nozzle boundary condition, the modes included in the approximating series expansion, particle characteristics and various control numbers. All the inputs are supplied to the main program. The next subsection gives a description of the necessary inputs.

In the second section of the program, the axial acoustic eigenvalues are calculated by means of subroutines EIGVAL and FCNS, and the integrals of the product of two axial eigenfunctions are computed by means of subroutines AXIAL1 and UBAR. The complex linear coefficients are then calculated according to Equations (C-1) through (C-7) and normalized by dividing by the coefficient of the highest derivative (i.e. $C_o(j,j)$ in Equations (22)).

In the third section the integrals of products of three axial eigenfunctions are computed using the subroutine AXIAL2. The complex nonlinear coefficients are obtained from Equations (C-8) through (C-11) and are then normalized.

In the fourth section the normalized complex coefficients are used to obtain coefficients for the equivalent system of real differential equations obtained by separating the real and imaginary parts of the complex equations. Since the axial eigenfunctions are not orthogonal, the resulting system of equations may be coupled in the highest derivative terms. Therefore a matrix inversion procedure is used to obtain the coefficients of an equivalent system which is not coupled in the highest derivatives. The subroutine GJR

performs the matrix inversion.

In the last section, the computed values of the coefficients are either printed out or stored on disk or both as desired.

Description of Input. The input data consists of the steady-state Mach numbers, the type of nozzle used, the various particle and gas constants, information about the modes used in the series expansion, and various control numbers. The input must be supplied to the program by means of punched cards. All real numbers must be punched with a decimal point in F10.0 format, while all integers must be punched in I5 format in the rightmost locations of the allocated field of 5 columns. For instance, in the second card, described below, the format is (2F10.0,I5).

A list of necessary input data is described below. The units of all the dimensional data are also indicated in this description. As can be observed from this description, these data must be specified in metric units. A sample input is also given at the end of this section.

The first card gives the title of the case, in columns 1 through 70.

Second card: GAM, UE, NØZZLE

GAM is the specific heat ratio.

UE is the steady state Mach number at the nozzle entrance.

NØZZLE specifies the type of nozzle used:

NØZZLE = 0 quasi-steady.

NØZZLE = 1 conventional nozzle.

Third card: NJMAX, NØNLIN, NEGL, NØUT, NPRTKL

NJMAX is the number of mode-amplitude functions in the assumed series solution.

The coefficients computed are determined by NØNLIN as follows:

NØNLIN = 0 linear coefficients only.

NØNLIN = 1 both linear and nonlinear coefficients.

Coefficients to be neglected are determined by NEGL as follows:

NEGL = 0 terms smaller than 0.00001 are neglected.

NEGL = 1 linear terms smaller than SM1 and nonlinear terms smaller than SM2 are neglected.

The output is determined by NØUT as follows:

NØUT = 0 printed output only.

NØUT = 1 write into a file and print output.

NØUT = 2 write into a file only.

NPRTKL determines whether the particles are present:

NPRTKL = 0 particles not present.

NPRTKL = 1 particles present.

Next card (necessary only if NPRTKL = 1): DIA, RHØM, SP, TEMP, FREQ, CM

DIA is the particle diameter, in microns.

RHØM is the density of the particle material, in kg/m^3.

SP is the ratio of the specific heats of particle material and gas.

TEMP is the chamber temperature, in degrees Kelvin.

FREQ is the frequency of oscillation in pure gas, in Hertz.

CM is the particle loading.

Next card (necessary only if NEGL = 1): SM1, SM2

SM1 and SM2 are as defined above.

Next NJMAX cards (necessary only if NØZZLE = 1): J, AMPL(J), PHASE(J)

AMPL(J) is the magnitude of the nozzle admittance for the Jth mode.

PHASE(J) is the phase of the nozzle admittance for the Jth mode.

Next NJMAX cards: J, L(J), NAME(J)

Each mode-amplitude is assigned an integer J.

The mode is specified by the index L(J).

L(J) is the axial mode number and must not exceed NJMAX.

NAME(J) is a four-character name for the Jth mode.

Description of the Subroutines. The different tasks performed by the program SOLID1 were outlined earlier in this section. This subsection explains the different subroutines which are involved in performing these tasks.

SUBRØUTINE EIGVAL (L,SMN, GAMMA, ZE, YAMPL, YPHASE, RESULT). This subroutine, called from the main program, computes the complex axial acoustic eigenvalues for a cylindrical chamber with a hard wall at one end and a nozzle at the other end. The amplitude and phase of the nozzle admittance is specified in the argument list by the variables YAMPL and YPHASE respectively. L specifies the axial mode number for which the acoustic eigenvalue is required. SMN indicates the transverse frequency and is set zero in the current program since only axial modes are considered. ZE is the nondimensional length of the chamber and equals 1. The computed value of the complex axial acoustic eigenvalue is obtained from this subroutine through the argument variable, RESULT.

This subroutine computes the real and imaginary parts of the eigenvalue (ϵ and η respectively) by solving a pair of simultaneous transcendental equations, $f(x,y)=0$ and $g(x,y)=0$, which are obtained from the wave equation for the case of no mean flow, combustion or particles. The roots ϵ and η of this system of transcendental equations are calculated by a method of successive approximations using Newton's method.

<u>SUBRØUTINE FCNS(X,Y,ZE,F,G,FX,FY,GX,GY)</u>. This subroutine is called by the subroutine EIGVAL at every iteration in the successive approximation scheme. It computes the functions F and G, and their partial derivatives FX, FY, GX, and GY with respect to X and Y. Here F and G are the functions whose roots are the desired axial eigenvalues. The value of these functions F and G and their partial derivatives are needed in the recursion formulas

$$\epsilon_{i+1} = \epsilon_i - \left[\frac{f \dfrac{\partial g}{\partial \eta} - g \dfrac{\partial f}{\partial \eta}}{\dfrac{\partial f}{\partial \epsilon}\dfrac{\partial g}{\partial \eta} - \dfrac{\partial g}{\partial \epsilon}\dfrac{\partial f}{\partial \eta}} \right]_i$$

$$\eta_{i+1} = \eta_i - \left[\frac{g \dfrac{\partial f}{\partial \epsilon} - f \dfrac{\partial g}{\partial \epsilon}}{\dfrac{\partial f}{\partial \epsilon}\dfrac{\partial g}{\partial \eta} - \dfrac{\partial g}{\partial \epsilon}\dfrac{\partial f}{\partial \eta}} \right]_i$$

where ϵ_{i+1} and η_{i+1} are the $(i+1)^{th}$ approximations to the real and imaginary parts of the eigenvalue.

<u>SUBRØUTINE AXIAL1 (NØPT,NP,NJ,UE,ZE,RESULT)</u>. This subroutine calculates the different integrals which appear in the expressions for the coefficients of the linear terms in Equations (22) and (23) according to the value of NØPT. The computed value of the desired integral is obtained as the argument variable RESULT. The different integrals that can be computed from this subroutine are:

$$\text{NØPT} = 1 \qquad \text{RESULT} = \int_o^{ZE} X_p X_j^* \, dx$$

$$\text{NØPT} = 2 \qquad \text{RESULT} = \int_o^{ZE} \frac{d^2 X_p}{dx^2} X_j^* \, dx$$

$$N\emptyset PT = 3 \qquad RESULT = \int_o^{ZE} \frac{d\bar{u}}{dx} X_p \; X_j^* \, dx$$

$$N\emptyset PT = 4 \qquad RESULT = \int_o^{ZE} \bar{u} \; \frac{dX_p}{dx} \; X_j^* \, dx$$

The subscripts p(=NP) and j(=NJ) denote the axial mode numbers, and X_p and X_j are the axial eigenfunctions for the p^{th} and j^{th} mode. The asterisk denotes the complex conjugate of the quantity. The eigenvalues, which are required to compute the eigenfunctions, are obtained from the main program through blank common. The integrals for NØPT = 1 and NØPT = 2 are evaluated analytically, but the last two integrals, which involve the mean flow velocity and its derivative, are evaluated numerically using Simpson's Rule. For these cases the value of the mean flow velocity and its derivative are obtained by calling the subroutine UBAR.

SUBRØUTINE AXIAL2 (NØPT, NCØNJ, NP, NQ, NJ, ZE, RESULT). This subroutine computes the integrals which appear in expressions for the coefficients of the nonlinear terms in Equations (22). The combination of integers NØPT and NCØNJ determines the integral that is computed and is available as RESULT. The three basic forms of the integral are specified by NØPT as follows:

$$N\emptyset PT = 1 \qquad RESULT = \int_o^{ZE} X_p \, X_q \, X_j^* \, dx$$

$$N\emptyset PT = 2 \qquad RESULT = \int_o^{ZE} \frac{dX_p}{dx} \, \frac{dX_q}{dx} \, X_j^* \, dx$$

$$N\emptyset PT = 3 \qquad RESULT = \int_o^{ZE} \frac{d^2 X_p}{dx^2} \, X_q \, X_j^* \, dx$$

When NCØNJ = 1, these basic forms are calculated. For NCØNJ = 2 the second function in the above integrands is replaced by its complex conjugate, while for NCØNJ = 3 the first function in the above integrands is replaced by its complex conjugate. For NCØNJ = 4, both the first and the second functions in these integrands are replaced by their complex conjugates. In these expressions X_p, X_q and

X_j are the axial acoustic eigenfunctions for the p^{th}, q^{th} and j^{th} axial modes (p(=NP), q(=NQ) and j(=NJ) are the axial mode numbers). The subroutine obtains the value of the acoustic eigenvalues from the main program through blank common space.

All the above integrals are evaluated in this subroutine analytically.

SUBRØUTINE UBAR (NØPT, UE, ZE, Z, RESULT). This subroutine is called by subroutine AXIAL1 and it calculates the steady-state velocity and its derivative at the axial location Z in a motor whose exit Mach number is UE. For NØPT = 1 the velocity is calculated, while for NØPT = 2 the derivative of the velocity is calculated. In the present program, a linear steady-state velocity distribution is assumed, which varies from zero at Z = 0 to UE at Z = ZE. While this computation could have been easily carried out in the calling program itself, a separate subroutine is provided for the steady-state velocity distribution so that more realistic velocity distributions can be conveniently incorporated in the motor program if desired.

SUBRØUTINE GJR(A, NC, NR, N, MC, JC, V). This is a matrix inversion routine. Here NC and NR are dimensions of the matrix A to be inverted, but only the first N x N elements of A are inverted, and the inverted matrix replaces the original matrix under the name A. V(1) should be set equal to 1 in the calling program to achieve the matrix inversion. If there is trouble (singularity) in the matrix inversion, a message is printed out. This subroutine is taken from the MATHPACK library for the UNIVAC 1100 series computers with suitable modifications to run on CDC 6000 series computers.

CØMPLEX FUNCTIØN CCØSH(X). This function calculates the hyperbolic cosine (i.e., cosh) of a complex number X.

CØMPLEX FUNCTIØN CSINH(X). This function calculates the hyperbolic sine (i.e., sinh) of a complex number X.

Both CCØSH(X) and CSINH(X) can be omitted in computing facilities where complex arguments are acceptable in the hyperbolic functions provided in their library.

Description of Output. The coefficients calculated by program SOLID1 are printed or stored on disk according to the value of the control numbers NØUT as indicated in the section on inputs. These two output modes will now be discussed.

Printed output is the only output obtained when NØUT = 0, which is used for checkout purposes only. Printed output can be obtained in conjunction with

disk storage mode by giving the value 1 to NØUT.

The first page of the printed output gives a restatement of the input parameters. The page is headed by the title of the case, and it gives the values of all the particle and gas constants. This is followed by information about the modes included in the series expansion, their eigenvalues and nozzle admittance values. In the following pages, the decoupled linear and nonlinear coefficients are printed out in the matrix format.

A sample printed output for the five term series used in the sample case is given in the next subsection.

Disk storage is the most convenient means of storing the output of Program SOLID1. This mode of output is obtained by setting NØUT = 1 or NØUT = 2. The output is written in a format which corresponds to the input format for SOLID2 so that the two programs can be run in tandem with ease. The disk into which the output is written is given the I/O device number 9. The control statement needed to request this number for I/O depends on the computer facilities used.

<u>Sample Case</u>. A sample case is presented in this section to facilitate checkout and to illustrate the I/O procedure. This case refers to a motor with exit Mach number $\bar{M}_e = 0.078$. The average diameter of the particles is 2.5 microns and particle loading is 0.1. The pure gas frequency of oscillation is 1071 Hertz, and the mean temperature in the chamber is $3525^{\circ}K$. A quasi-steady nozzle is employed and the specific heat ratio is 1.23. It is desired to consider the first five longitudinal modes in the series expansion for the velocity potential. A printed output as well as disk storage of the output is required so that they may be used for checking out Program SOLID2 later.

An input deck needed for fulfilling the above conditions is illustrated in Table 1. The printed output generated by the program with this output deck is shown in the following pages.

```
TEST CASE FØR SØLID1
      1.23     0.078    0
    5    1    0    1    1
       2.5    4000.0      0.68    3525.0    1071.0       0.1
    1    1 1L
    2    2 2L
    3    3 3L
    4    4 4L
    5    5 5L
```

TEST CASE FOR SOLID1

GAMMA = 1.23000   UE = .0780

QUASI-STEADY NOZZLE.

PARTICLE DIA (IN MICRONS) = 2.50   CM = .1000   FREQ (IN HERTZ) = 1071.0

CHAMBER TEMP (IN DEG K) = 3525.0   SP = .6800   RHOM (IN KG/CUBIC METER) = 4000.0

PARTICLE DRAG COEFFICIENT, K = 29.3156

NAME	J	L	EPS	ETA	YR	YI
1L	1	1	3.14159	.00828	.00683	0.00000
2L	2	2	6.28319	.00828	.00683	0.00000
3L	3	3	9.42478	.00828	.00683	0.00000
4L	4	4	12.56637	.00828	.00683	0.00000
5L	5	5	15.70796	.00828	.00683	0.00000

DECOUPLED COEFFICIENT OF B(P): C(1,J,P)

J \ P	1	2	3	4	5	6	7	8	9	10
1	9.869102	-.000061	.001005	-.104020	-.001576	.156029	.002147	-.208038	-.002718	.260047
2	.000001	9.869102	.104020	.001005	-.156029	-.001576	.208038	.002147	-.260047	-.002718
3	.000031	-.052013	39.478029	.000003	.000548	-.156038	-.000777	.208050	.001005	-.260063
4	.052013	.000091	-.000003	39.478029	.156038	.000548	-.208050	-.000777	.260063	.001005
5	.000137	.052013	-.000137	-.104026	88.826508	.000005	-.000137	-.208052	.000137	.260065
6	-.052013	.000137	.104026	-.000137	-.000005	88.826508	.208052	-.000137	-.260065	.000137
7	-.000365	-.052012	.000594	.104024	-.000822	-.156037	157.914653	.000004	-.001279	-.260062
8	.052012	-.000365	-.104024	.000594	.156037	-.000822	-.000004	157.914653	.260062	-.001279
9	.000703	.052006	-.001279	-.104017	.001850	.156026	-.002421	-.208035	246.743034	-.000012
10	-.052008	.000708	.104017	-.001279	-.156026	.001850	.208035	-.002421	.000012	246.743034

DECOUPLED COEFFICIENT OF B(P): C(1,J,P)

J \ P	11	12	13	14	15	16	17	18	19	20
1	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
3	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
7	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
9	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

DECOUPLED COEFFICIENT OF THE DERIVATIVE OF B(P): C(2,J,P)

J \ P	1	2	3	4	5	6	7	8	9	10
1	.267107	.001976	-.432544	-.002414	.367537	.003336	-.349332	-.004171	.341522	.005391
2	-.001976	.267107	.002414	-.432544	-.003336	.367537	.004171	-.349332	-.005391	.341522
3	.087440	-.001297	.267113	.001493	-.578157	-.001708	.432557	.002679	-.387384	-.004068
4	.001297	.087440	-.001493	.267113	.001708	-.578157	-.002679	.432557	.004068	-.387384
5	-.022439	.000712	.233038	-.001405	.267121	.001585	-.729714	-.001988	.504076	.003758
6	-.000712	-.022439	.001405	.233038	-.001585	.267121	.001988	-.729714	-.003758	.504076
7	.004238	-.000439	-.087434	.000952	.384569	-.001780	.267141	.002332	-.883266	-.003984
8	.000439	.004238	-.000952	-.087434	.001780	.384569	-.002332	.267141	.003984	-.883266
9	.003563	.000247	.042857	-.000782	-.158913	.001665	.538056	-.003301	.267201	.006367
10	-.000247	.003563	.000782	.042857	-.001665	-.158913	.003301	.538056	-.006367	.267201

DECOUPLED COEFFICIENT OF THE DERIVATIVE OF B(P): C(2,J,P)

J \ P	11	12	13	14	15	16	17	18	19	20
1	-.000828	-.000019	.004415	.000024	-.003725	-.000033	.003532	.000042	-.003449	-.000055
2	.000019	-.000826	-.000024	.004415	.000033	-.003725	-.000042	.003532	.000055	-.003449
3	-.001104	.000013	-.000828	-.000015	.005960	.000017	-.004415	-.000028	.003942	.000042
4	-.000013	-.001104	.000015	-.000828	-.000017	.005960	.000023	-.004415	-.000042	.003942
5	.000414	-.000006	-.002649	.000015	-.000828	-.000017	.007568	.000021	-.005174	-.000040
6	.000005	.000414	-.000015	-.002649	.000017	-.000828	-.000021	.007568	.000040	-.005174
7	-.000221	.000005	.001104	-.000011	-.004257	.000020	-.000828	-.000026	.009198	.000043
8	-.000005	-.000221	.000011	.001104	-.000020	-.004257	.000026	-.000828	-.000043	.009198
9	.000138	-.000005	-.000630	.000010	.001862	-.000020	-.005836	.000037	-.000829	-.000069
10	.000005	.000138	-.000010	-.000630	.000020	.001862	-.000037	-.005836	.000069	-.000829

DECOUPLED COEFFICIENT OF THE TERM, MULTIPLYING K: C(3,J,P)

J \ P	1	2	3	4	5	6	7	8	9	10
1	.100519	.000000	.000000	-.000000	-.000000	.000000	-.000000	-.000000	-.000000	.000000
2	.000000	.100519	.000000	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000
3	.000000	.000000	.100519	.000000	.000000	-.000000	-.000000	.000000	-.000000	-.000000
4	-.000000	.000000	-.000000	.100519	.000000	.000000	-.000000	-.000000	.000000	-.000000
5	.000000	.000000	.000000	-.000000	.100519	.000000	.000000	-.000000	.000000	0.000000
6	-.000000	.000000	.000000	-.000000	-.000000	.100519	.000000	-.000000	.000000	.000000
7	-.000000	-.000000	.000000	.000000	0.000000	-.000000	.100519	-.000000	0.000000	.000000
8	.000000	-.000000	-.000000	.000000	.000000	-.000000	.000000	.100519	-.000000	-.000000
9	.000000	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.100519	-.000000
10	-.000000	.000000	.000000	-.000000	-.000000	.000000	.000000	-.000000	.000000	.100519

DECOUPLED COEFFICIENT OF THE TERM, MULTIPLYING K: C(3,J,P)

J \ P	11	12	13	14	15	16	17	18	19	20
1	-.100519	-.000000	-.000000	.000000	.000000	-.000000	.000000	.000000	.000000	-.000000
2	-.000000	-.100519	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	.000000
3	-.000000	-.000000	-.100519	-.000000	-.000000	.000000	.000000	-.000000	.000000	.000000
4	.000000	-.000000	.000000	-.100519	-.000000	-.000000	.000000	.000000	-.000000	.000000
5	-.000000	-.000000	-.000000	.000000	-.100519	-.000000	-.000000	.000000	-.000000	0.000000
6	.000000	-.000000	-.000000	.000000	.000000	-.100519	-.000000	.000000	-.000000	-.000000
7	.000000	.000000	-.000000	-.000000	0.000000	.000000	-.100519	.000000	0.000000	-.000000
8	-.000000	.000000	.000000	-.000000	-.000000	.000000	-.000000	-.100519	.000000	.000000
9	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	.000000	-.100519	.000000
10	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	-.000000	-.100519

DECOUPLED COEFFICIENT OF THE REAL PART OF THE COMBUSTION TERM: E(J,P,1)

J \ P	1	2	3	4	5	6	7	8	9	10
1	-.094555	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	.000000
2	-.000000	-.094555	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000
3	-.000000	.000000	-.094555	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000
4	-.000000	-.000000	-.000000	-.094555	.000000	-.000000	-.000000	.000000	.000000	-.000000
5	.000000	-.000000	-.000000	.000000	-.094555	-.000000	-.000000	-.000000	.000000	.000000
6	.000000	.000000	-.000000	-.000000	.000000	-.094555	.000000	-.000000	-.000000	.000000
7	-.000000	.000000	.000000	-.000000	-.000000	.000000	-.094555	-.000000	-.000000	-.000000
8	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	-.094555	.000000	-.000000
9	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	-.094555	-.000000
10	.000000	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	-.094555

DECOUPLED COEFFICIENT OF THE IMAGINARY PART OF THE COMBUSTION TERM: E(J,P,2)

J \ P	1	2	3	4	5	6	7	8	9	10
1	.000000	.094555	-.000000	.000000	.000000	-.000000	-.000000	.000000	.000000	-.000000
2	-.094555	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	.000000
3	.000000	.000000	.000000	.094555	-.000000	.000000	.000000	-.000000	-.000000	.000000
4	-.000000	.000000	-.094555	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000
5	-.000000	-.000000	.000000	.000000	-.000000	.094555	-.000000	.000000	.000000	-.000000
6	.000000	-.000000	-.000000	.000000	-.094555	-.000000	-.000000	-.000000	.000000	.000000
7	.000000	.000000	-.000000	-.000000	.000000	.000000	-.000000	.094555	-.000000	.000000
8	-.000000	.000000	.000000	-.000000	-.000000	.000000	-.094555	-.000000	-.000000	-.000000
9	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	.000000	-.000000	.094555
10	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	-.094555	-.000000

COEFFICIENTS IN THE PARTICLE EQUATIONS: CPAR(J,P)

J \ P	1	2	3	4	5	6	7	8	9	10
1	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
3	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
7	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
9	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

COEFFICIENTS IN THE PARTICLE EQUATIONS: CPAR(J,P)

J \ P	11	12	13	14	15	16	17	18	19	20
1	.116395	.000893	-.206921	-.001111	.174585	.001569	-.165530	-.001984	.161645	.002591
2	-.000893	.116395	.001111	-.206921	-.001569	.174585	.001984	-.165530	-.002591	.161645
3	.051730	-.000609	.116397	.000707	-.279351	-.000814	.206927	.001296	-.184755	-.001987
4	.000609	.051730	-.000707	.116397	.000814	-.279351	-.001296	.206927	.001987	-.184755
5	-.019397	.000354	.124153	-.000699	.116401	.000788	-.354739	-.000989	.242502	.001869
6	-.000354	-.019397	.000699	.124153	-.000788	.116401	.000989	-.354739	-.001869	.242502
7	.010343	-.000254	-.051727	.000510	.199527	-.000922	.116411	.001196	-.431119	-.002318
8	.000254	.010343	-.000510	-.051727	.000922	.199527	-.001196	.116411	.002318	-.431119
9	-.006463	.000214	.029553	-.000480	-.087281	.000919	.275874	-.001732	.116441	.003258
10	-.000214	-.006463	.000480	.029553	-.000919	-.087281	.001732	.275874	-.003258	.116441

COEFFICIENTS IN THE PARTICLE EQUATIONS: CPAR(J,P)

J \ P	1	2	3	4	5	6	7	8	9	10
1	-1.000000	.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	.000000	-.000000
2	-.000000	-1.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	.000000
3	-.000000	-.000000	-1.000000	-.000000	-.000000	.000000	-.000000	-.000000	.000000	.000000
4	.000000	-.000000	.000000	-1.000000	-.000000	-.000000	.000000	.000000	-.000000	0.000000
5	-.000000	-.000000	-.000000	.000000	-1.000000	-.000000	-.000000	.000000	-.000000	-.000000
6	.000000	-.000000	-.000000	-.000000	.000000	-1.000000	-.000000	-.000000	.000000	-.000000
7	.000000	.000000	-.000000	-.000000	0.000000	-.000000	-1.000000	.000000	0.000000	-.000000
8	-.000000	.000000	.000000	.000000	-.000000	.000000	-.000000	-1.000000	.000000	.000000
9	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	.000000	-1.000000	.000000
10	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	.000000	-1.000000

COEFFICIENTS IN THE PARTICLE EQUATIONS: CPAR(J,P)

J \ P	11	12	13	14	15	16	17	18	19	20
1	1.000000	-.000000	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000
2	.000000	1.000000	.000000	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000
3	.000000	.000000	1.000000	.000000	.000000	-.000000	.000000	.000000	-.000000	-.000000
4	-.000000	.000000	-.000000	1.000000	.000000	.000000	-.000000	-.000000	.000000	0.000000
5	.000000	.000000	.000000	-.000000	1.000000	.000000	.000000	-.000000	.000000	.000000
6	-.000000	.000000	.000000	.000000	-.000000	1.000000	.000000	.000000	-.000000	.000000
7	-.000000	-.000000	.000000	.000000	0.000000	.000000	1.000000	-.000000	0.000000	.000000
8	.000000	-.000000	-.000000	-.000000	.000000	-.000000	.000000	1.000000	-.000000	-.000000
9	.000000	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000	1.000000	-.000000
10	-.000000	.000000	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000	1.000000

DECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION FOR B(1)

P \ J	1	2	3	4	5	6	7	8	9	10
1	-.000380	-.038264	13.692389	-.010060	-.000752	.057837	.000460	-.032653	.000899	.023676
2	-.038313	-.006350	.019021	-.015937	-.143228	-.057781	.120355	.031676	-.113435	-.075595
3	15.550245	.015463	-.001496	-.060807	55.029566	-.056398	.000512	.189087	-.001525	-.110003
4	.011323	-.026345	-.060881	-.125516	.074478	.004360	-.337320	-.276405	.266250	.198513
5	-.000980	-.125264	43.792663	.062120	-.000777	-.087603	109.008728	-.125457	.000386	.353718
6	.016660	-.016518	-.027213	-.008390	-.067689	-.435345	.153947	.160530	-.592367	-.502355
7	.000992	.105982	.000503	-.304149	101.676899	.133201	-.002220	-.115769	160.634262	-.217844
8	.015631	-.016631	.133628	-.234061	-.068089	.151533	-.115904	-.762329	.256692	.256848
9	.000705	-.100007	-.001230	.239061	.000257	-.544346	171.207646	.227806	-.003835	-.144050
10	-.034375	-.044048	-.049518	.157441	.313583	-.444776	-.172209	.244867	-.144195	-1.162884

DECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION FOR B(2)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	.007927	.038397	.016962	-.019406	.056752	.143619	-.031252	-.120516	.075323	.113364
2	.038445	-.000374	.009046	18.692379	-.056690	-.000750	.030266	.000447	-.021023	.000908
3	.027254	-.012349	.123697	.061848	-.001438	-.075779	.273972	.335250	-.197601	-.265413
4	-.016063	15.550235	.061321	-.001477	.053410	55.029543	-.166055	.000536	.105395	-.001550
5	.015589	-.015441	.011110	.024180	.431082	.089816	-.154783	-.154885	.497956	.592364
6	.126235	-.000969	-.063756	49.792642	.089900	-.000746	.121296	109.008692	-.379535	.000427
7	.017031	-.018040	.231782	-.130492	-.146059	.083918	.754858	.117865	-.247347	-.257100
8	-.107237	.000961	.305811	.000524	-.134462	101.676865	.117979	-.002169	.212256	180.634202
9	.043785	.036982	-.156566	.045139	.440614	-.309408	-.235730	.166676	1.170704	.146361
10	.101555	.000712	-.239473	-.001300	.545078	.000324	-.225364	171.207591	.148504	-.003753

DECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION FOR B(3)

P \ J	1	2	3	4	5	6	7	8	9	10
1	-10.916937	.033350	-.000162	-.095338	28.562490	.006989	-.001239	.070901	-.000520	-.035760
2	.038688	.016267	-.032829	.096272	-.000423	-.034335	-.171620	-.071361	.134532	.101699
3	-.000698	-.048274	.001318	.076344	-.001268	-.175173	74.768228	-.019138	-.003655	.214548
4	-.102772	.102738	.076393	.018484	.018009	.175453	.036728	.078427	-.382412	-.324417
5	20.183188	.003238	-.001249	.002299	.000976	.096164	-.000127	-.295234	138.620144	-.057862
6	.045641	-.054746	-.172478	.172952	.096203	.242051	.087591	.159941	.066276	.122281
7	-.001373	-.141602	62.199038	.029814	.000034	.068713	.002762	.122184	-.000773	-.448090
8	.001719	-.001839	.023366	.074012	-.288287	.145525	.122159	.403520	.180282	.285275
9	-.000556	.114679	-.000438	-.330716	121.861329	.070537	-.000593	.163988	.004718	.149223
10	.035169	.065785	.127139	-.259826	-.307705	.113817	-.437266	.287659	.149294	.612561

DECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION FOR B(4)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	-.015839	-.038548	-.098849	.032959	.035739	-.000763	.069985	.172909	-.101190	-.134758
2	-.033047	-10.917000	.098786	-.000157	-.009077	28.562484	-.070439	-.001229	.034348	-.000530
3	-.103216	.103185	-.016061	-.077027	-.176976	-.016201	-.074640	-.040122	.321431	.383931
4	.048424	-.000093	-.077075	.001309	.177264	-.001262	.019083	74.768222	-.214423	-.000637
5	.055808	-.046023	-.174221	.174762	-.241076	-.097956	-.163132	-.085739	-.115674	-.090719
6	-.004461	20.183161	-.000371	-.001243	-.097994	.000971	.297368	-.000126	.059504	138.620134
7	.000726	-.000840	-.070972	-.023370	-.148356	.290578	-.401700	-.123312	-.290691	-.184487
8	.143196	-.001365	-.033233	62.199034	-.066839	.000035	-.123366	.002757	.450333	-.000770
9	-.065342	-.034715	.257226	-.126670	-.107945	.008832	-.272609	.439654	-.609643	-.150357
10	-.115968	-.000561	.332589	-.000426	-.074809	121.861322	-.162131	-.000591	-.150426	.004709

DECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION FOR B(5)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	.000058	.022851	-20.787178	.047571	-.000259	-.152392	38.432588	.023855	-.000394	.086286
2	.022653	-.038815	.054722	-.020997	-.031943	.152107	-.015854	-.048942	-.203693	-.175836
3	-23.929455	.052680	-.000677	-.131550	.000525	.139525	-.000022	-.254444	94.506429	.002351
4	.057982	-.020261	-.131603	.069136	.067756	-.140436	.061520	.107985	.015635	.054388
5	-.000050	-.074901	.000578	.079731	-.000795	-.114272	-.001039	.168516	-.001209	-.413072
6	-.159954	.159759	.144690	-.145641	-.114292	-.197205	.046194	-.020855	.172759	.245075
7	22.721353	-.002363	.000347	.020362	-.001077	.057733	-.002686	-.133647	-.001119	.258614
8	.076346	-.082037	-.242451	.074375	.190442	-.013183	-.133681	-.298529	.022789	-.071243
9	.000065	-.157415	72.512361	.015481	-.000848	.124473	-.001138	.035162	-.004602	-.157976
10	-.018527	-.114616	.059495	.082934	-.390422	.205264	.258637	-.063036	-.158021	-.435441

DECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION FOR B(6)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	.038203	-.023171	.021868	-.053378	-.152945	.032282	.050780	.013921	.174061	.205049
2	-.023173	.000059	-.047327	-20.737181	.152662	-.000256	-.023660	33.432585	-.066584	-.000388
3	.021244	-.057616	-.069898	.131403	.140897	-.066592	-.109666	-.056351	-.079950	-.019120
4	-.051630	-23.929458	.131455	-.000667	-.141814	.000521	.255513	-.000030	-.000394	94.508430
5	-.160433	.160241	.146041	-.146999	.196782	.115831	.021680	-.046042	-.248796	-.170220
6	.075117	-.000045	-.080766	.000573	.115849	-.000793	-.190941	-.001030	.412755	-.001225
7	.053231	-.079075	-.075770	.243357	.013893	-.192878	.297776	.134112	.072675	-.021395
8	.000485	22.721350	-.017743	.000340	-.057686	-.001069	.134144	-.002658	-.261510	-.001107
9	.113338	.016860	-.079470	-.058340	-.206320	.390446	.064322	-.261408	.434213	.156099
10	.159002	.000067	-.019495	72.512365	-.122163	-.000863	-.033861	-.001127	.158142	-.004501

DECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION FOR B(7)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	.006166	-.009574	.000548	.040252	-30.657002	.061386	-.000487	-.205378	48.301338	.038150
2	-.009572	.021319	.053239	-.040397	.069012	-.034513	-.031446	.204392	-.029912	.070164
3	.006592	.059202	-43.666233	.066383	.000212	-.204302	-.001054	.198217	-.000713	-.328708
4	.046432	-.049142	.078041	.033064	-.166372	.204378	.065390	.022251	.099176	.146582
5	-39.036405	.073697	.000212	-.133466	.000702	.154719	.000972	-.180517	-.000536	.259623
6	.073479	-.029776	-.217846	.217834	.154723	.208366	-.105132	-.043602	.017128	-.052137
7	-.000182	-.112984	-.001217	.096196	.000985	-.115876	.002873	.153690	.001032	-.218976
8	-.215496	.215518	.204971	.046483	-.186154	-.050838	.153710	.262869	-.094035	-.006328
9	23.162878	-.003835	-.000244	.024730	-.000584	.046553	.001019	-.104252	.004804	.171791
10	.113244	.087865	-.303436	.083235	.259673	-.030154	-.222593	-.012662	.171821	.359359

DECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION FOR B(8)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	-.021103	.009606	.039866	-.053786	.035857	-.068089	-.205999	.032252	-.067881	.027940
2	.009604	.000167	-.040508	.000547	-.060999	-30.657002	.205621	-.000490	-.037375	48.301392
3	.048022	-.048729	-.031140	-.076830	-.205555	.166246	-.021674	-.066177	-.148867	-.097688
4	-.059808	.000591	-.065809	-43.668238	.205639	.000216	-.198033	-.001044	.328222	-.000730
5	.031395	-.072824	-.219084	.219080	-.207929	-.155949	.043171	.104159	.053053	-.015999
6	-.072604	-39.036407	.183497	.000216	-.155953	.000702	.181945	.000962	-.260515	-.000515
7	-.218400	.218439	-.046010	-.206942	.058453	.187549	-.262446	-.153136	.005674	.091548
8	.113677	-.000182	-.397193	-.001209	.114958	.000975	-.153155	.002878	.220469	.001019
9	-.066608	-.113523	-.084758	.303317	.030876	-.260466	.012078	.223987	-.358705	-.170641
10	.002133	23.162863	-.023602	-.000261	-.045452	-.000564	.101761	.001007	-.170670	.004308

DECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION FOR B(9)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	-.000241	.005504	-.000095	-.016612	.000661	.057441	-40.526500	.074339	.000053	-.256098
2	.005501	-.014834	-.024643	.016615	.065898	-.058185	.082469	-.047753	-.031720	-.006279
3	-.000077	-.027060	-.000257	.102048	-63.408228	.080509	.000996	-.276383	-.000199	.251774
4	-.020415	.020420	.102062	-.140365	.094005	-.027366	-.202050	-.162446	.066079	.019930
5	.000725	.101311	-66.645271	.085470	-.001169	-.282774	-.000278	.220931	.000278	-.240206
6	.081233	-.082133	.097331	-.027489	-.282752	-.319990	.174211	.116741	-.102608	-.037075
7	-56.237651	.096549	.001086	-.244467	-.000246	.187134	-.003926	-.190268	-.000399	.221519
8	.085132	-.036096	-.306250	-.198969	.230663	.126401	-.190277	-.266944	.144153	.061326
9	.000596	-.163022	-.000133	.121714	.000191	-.129195	-.000349	.154237	-.005974	-.193571
10	-.271445	-.127229	.264117	.065748	-.250109	-.056771	.227532	.067313	-.193591	-.328497

DECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION FOR B(10)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	.014717	-.005458	-.016259	.024642	.056752	-.086372	.049547	-.082027	.006900	.031746
2	-.005455	-.000242	.016260	-.000092	-.057491	.000655	-.074933	-40.526489	.257888	.000037
3	-.020044	.020047	.138540	-.102494	.030200	-.093368	.160648	.200913	-.019225	-.063441
4	.027035	-.000073	-.102508	-.000263	-.051091	-63.408218	.276675	.000977	-.251261	-.000175
5	.080466	-.081362	.030536	-.097847	.318054	.282102	-.116170	-.171000	.036578	.096712
6	-.101799	.000719	-.084883	-68.645261	.282079	-.001183	-.219994	-.000260	.239389	.000255
7	.038433	-.085577	.197160	.306450	-.125830	-.229582	.266560	.187366	-.060907	-.139297
8	-.096236	-56.237641	.243349	.001067	-.183836	-.000227	.187373	-.003941	-.220534	-.000383
9	.126135	.271304	-.065175	-.263087	.056349	.248897	-.067431	-.226350	.328074	.189948
10	.162712	.000581	-.118892	-.000108	.125179	.000168	-.149319	-.000333	.189967	-.005983

FORTRAN Source Code.

```
      PROGRAM SOLID1(INPUT,OUTPUT,DATA,
     1              TAPE5=INPUT,TAPE6=OUTPUT,TAPE9=DATA)
C
C
C     **************** PROGRAM SOLID1 ***********************************
C
C
C          THIS PROGRAM COMPUTES THE COEFFICIENTS WHICH APPEAR
C     IN THE DIFFERENTIAL EQUATIONS WHICH GOVERN THE MODE-AMPLITUDE
C     FUNCTIONS.  THESE COEFFICIENTS CAN BE WRITTEN INTO A FILE
C     FOR INPUT TO PROGRAM SOLID2.
C
C     THE FOLLOWING INPUTS ARE REQUIRED:
C
C     THE FIRST CARD GIVES THE TITLE OF THE CASE.
C
C     SECOND CARD: GAM, UE, NOZZLE
C        GAM IS THE SPECIFIC HEAT RATIO.
C        UE IS THE STEADY STATE MACH NUMBER AT THE NOZZLE ENTRANCE.
C        NOZZLE SPECIFIES THE TYPE OF NOZZLE USED:
C           NOZZLE = 0      QUASI-STEADY
C           NOZZLE = 1      CONVENTIONAL NOZZLE
C
C     THIRD CARD: NJMAX, NONLIN, NEGL, NOUT, NPRTKL
C        NJMAX IS THE NUMBER OF MODE-AMPLITUDE FUNCTIONS IN THE ASSUMED
C        SERIES SOLUTION.
C        THE COEFFICIENTS COMPUTED ARE DETERMINED BY NONLIN AS FOLLOWS:
C           NONLIN = 0   LINEAR COEFFICIENTS ONLY
C           NONLIN = 1   BOTH LINEAR AND NONLINEAR COEFFICIENTS.
C        COEFFICIENTS TO BE NEGLECTED ARE DETERMINED BY NEGL
C        AS FOLLOWS:
C           NEGL = 0   TERMS SMALLER THAN 0.00001 ARE NEGLECTED.
C           NEGL = 1   LINEAR TERMS SMALLER THAN SM1 AND NONLINEAR
C                      TERMS SMALLER THAN SM2 ARE NEGLECTED.
C        THE OUTPUT IS DETERMINED BY NOUT AS FOLLOWS:
C           NOUT = 0  PRINTED OUTPUT ONLY
C           NOUT = 1  WRITE INTO A FILE AND PRINT OUTPUT.
C           NOUT = 2  WRITE INTO A FILE ONLY.
C        NPRTKL DETERMINES WHETHER THE PARTICLES ARE PRESENT:
C           NPRTKL = 0   PARTICLES NOT PRESENT.
C           NPRTKL = 1   PARTICLES PRESENT.
C
C     NEXT CARD ( ONLY IF NPRTKL=1): DIA, RHOM, SP, TEMP, FREQ, CM
C        DIA IS THE PARTICLE DIAMETER, IN MICRONS.
C        RHOM IS THE DENSITY OF THE PARTICLE MATERIAL, IN KG/M**3.
C        SP IS THE RATIO OF THE SPECIFIC HEATS OF PARTICLE MATERIAL
C             AND GAS.
C        TEMP IS THE CHAMBER TEMPERATURE, IN DEGREES KELVIN.
C        FREQ IS THE FREQUENCY OF OSCILLATION IN PURE GAS, IN HERTZ.
C        CM IS THE PARTICLE LOADING.
C
```

```
C
C     NEXT CARD (NECESSARY ONLY IF NEGL = 1): SM1, SM2
C          SM1 AND SM2 ARE AS DEFINED ABOVE.
C
C     NEXT NJMAX CARDS ( ONLY IF NOZZLE = 1): J, AMPL(J), PHASE(J)
C          AMPL(J) IS THE MAGNITUDE OF THE NOZZLE ADMITTANCE
C                   FOR THE J TH MODE.
C          PHASE(J) IS THE PHASE OF THE NOZZLE ADMITTANCE
C                   FOR THE J TH MODE.
C
C     NEXT NJMAX CARDS: J, L(J), NAME(J)
C          EACH MODE-AMPLITUDE IS ASSIGNED AN INTEGER J.
C          THE MODE IS SPECIFIED BY THE INDEX L(J).
C          L(J) IS THE AXIAL MODE NUMBER AND MUST NOT EXCEED NJMAX.
C          NAME(J) IS A FOUR-CHARACTER NAME FOR THE J TH MODE.
C
C     ******************************************************************
C
C
      DIMENSION      L(6), NAME(6), TITLE(7), AMPL(6), PHASE(6),
     1               V(2), C(3,12,24),C1(12,12),JC(12),
     2               E(12,12,2),D(12,12,12),
     3               KMAX(6), TSR(2,12), TSQ(12),TS(3,24),
     4               C1PAR(12,12), CPAR(2,12,24), TSPAR(2,12), KMAXPR(2)
      COMPLEX        CRSLT, CI, ZEJ, ZEP1, ZEP2, AX(5), AXINT(4,4),
     1               DCOEF, B(6), BC(6),
     2               YNOZ(6), CC(5,6,12),CNORM(12),
     3               CD1(6,6,6), CD2(6,6,6),
     4               CD3(6,6,6), CD4(6,6,6),
     5               CCPAR(3,6,12), CCOSH, CSINH
      COMMON      B
C
C     DATA INPUT.
C
      MAXMD = 6
      MAXMD2 = 12
      MAXMD4 = 24
      PI = 3.1415926536
      SM1 = 0.00001
      SM2 = 0.00001
      CI = (0.0,1.0)
C
C     INPUT PARAMETERS.
    4 READ (5,5000)   TITLE
      IF (EOF(5)) 600, 1
    1 CONTINUE
      READ (5,5001) GAM, UE, NOZZLE
      READ (5,5004) NJMAX, NONLIN, NEGL, NOUT, NPRTKL
      IF (NPRTKL .EQ. 1) READ (5,5006) DIA, RHOM, SP, TEMP, FREQ, CM
      GAMMA = GAM * (1.0 + SP*CM) / (1.0 + GAM*SP*CM)
      IF (NEGL .EQ. 1) READ (5,5005) SM1, SM2
      IF (NOZZLE .EQ. 1)  GO TO 5
```

```
C     COMPUTE ADMITTANCE FOR QUASI-STEADY NOZZLE.
      Y = (GAMMA - 1.0) * UE/(2.0 * GAMMA)
      DO 3 J = 1, NJMAX
      AMPL(J) = Y
      PHASE(J) = 0.0
    3 CONTINUE
      GO TO 7
    5 DO 6 I = 1, NJMAX
      READ (5,5003) J, AMPL(J), PHASE(J)
    6 CONTINUE
    7 DO 10 I = 1, NJMAX
      READ (5,5002) J, L(J), NAME(J)
   10 CONTINUE
C
      DO 12 J = 1, NJMAX
      THETA = PHASE(J) * PI/180.0
      YR = AMPL(J) * COS(THETA)
      YI = AMPL(J) * SIN(THETA)
      YNOZ(J) = CMPLX(YR,YI)
   12 CONTINUE
C
      NJMAX2 = NJMAX
      IF (NPRTKL .EQ. 1) NJMAX2 = 2 * NJMAX
      ZE = 1.0
      ZCOMB = 1.0
      CAX = GAMMA + 1.0
C
      RHOP = 0.0
      IF (NPRTKL .EQ. 0) GO TO 14
      VISC = 8.834 * 0.00001 * (TEMP/3485.)**0.66
      PARTKL = (9.0 * VISC) / (RHOM * FREQ * DIA * DIA * 10.**(-12))
      UPBYU = 2.0 / (1.0 + SQRT(1.0 + 8.0*UE/PARTKL))
      RHOP = CM/UPBYU
   14 CONTINUE
C
C     ******************************************************************
C
C     CALCULATE AXIAL ACOUSTIC EIGENVALUES.
C
C
C     COMPUTE EIGENVALUES.
      DO 40 J = 1, NJMAX
      LL = L(J)
      SMN = 0.0
      YAMPL = AMPL(J)
      YPHASE = PHASE(J)
      CALL EIGVAL(LL,SMN,GAMMA,ZE,YAMPL,YPHASE,CRSLT)
      B(J) = CRSLT
      BC(J) = CONJG(CRSLT)
   40 CONTINUE
```

```
C
C     ******************************************************************
C
C     CALCULATE LINEAR COEFFICIENTS.
C
      DO 100 NJ = 1, NJMAX
      DO 100 NP = 1, NJMAX2
C
C     ZERO COEFFICIENT ARRAYS.
      DO 105 KC = 1, 5
      CC(KC,NJ,NP) = (0.0,0.0)
  105 CONTINUE
      NPM = NP
      NJM = NJ
      IF (NP .GT. NJMAX) NPM = NP - NJMAX
C
C     CALCULATE AXIAL INTEGRALS.
  127 DO 130 NOPT = 1, 4
      CALL AXIAL1(NOPT,NPM,NJM,UE,ZE,CRSLT)
      AX(NOPT) = CRSLT
  130 CONTINUE
C
C     EVALUATE FUNCTIONS AT NOZZLE END.
      ZEJ = CCOSH(CI * BC(NJM) * ZE)
      ZEP1 = CCOSH(CI * B(NPM) * ZE)
      ZEP2 = CI * B(NPM) * CSINH(CI*B(NPM)*ZE)
C
      IF (NP .GT. NJMAX) GO TO 704
C
C     COEFFICIENT OF THE SECOND DERIVATIVE OF A(P).
      CC(1,NJ,NP) = AX(1)
C
C     COEFFICIENT OF A(P).
      CC(2,NJ,NP) = - AX(2) + ZEP2*ZEJ
C
C     COEFFICIENT OF THE FIRST DERIVATIVE OF A(P).
      CC(3,NJ,NP) = (CAX*AX(3) + (2.0,0.0)*AX(4)
     1              + GAMMA*YNOZ(NP)*ZEP1*ZEJ)
      CC(4,NJ,NP) = RHOP * AX(1)
      CC(5,NJ,NP) = - GAMMA * AX(3)
      GO TO 100
C
  704 CC(3,NJ,NP) = - (GAMMA - 1.0) * RHOP * UPBYU * AX(4)
      CC(4,NJ,NP) = - RHOP * AX(1)
C
  100 CONTINUE
C
C     NORMALIZE LINEAR COEFFICIENTS.
      DO 140 NJ = 1, NJMAX
      CNORM(NJ) = CC(1,NJ,NJ)
      DO 140 NP = 1, NJMAX2
      DO 140 KC = 1, 5
      CC(KC,NJ,NP) = CC(KC,NJ,NP)/CNORM(NJ)
  140 CONTINUE
```

```
C
      IF (NPRTKL .EQ. 0) GO TO 1005
      DO 1010 NJ = 1, NJMAX
      DO 1010 NP = 1, NJMAX2
      DO 1015 KC = 1, 3
      CCPAR(KC,NJ,NP) = (0.0,0.0)
 1015 CONTINUE
      NPM = NP
      IF (NP .GT. NJMAX)NPM = NP -NJMAX
      NJM = NJ
C     CALCULATE AXIAL INTEGRALS.
      DO 1020 NOPT = 1, 4
      CALL AXIAL1(NOPT,NPM,NJM,UE,ZE,CRSLT)
 1020 AX(NOPT) = CRSLT
      IF (NP .GT. NJMAX) GO TO 1025
      CCPAR(3,NJ,NP) = - AX(1)
      GO TO 1010
 1025 CCPAR(1,NJ,NP) = AX(1)
      CCPAR(2,NJ,NP) = UPBYU*(AX(4) + AX(3))
      CCPAR(3,NJ,NP) = AX(1)
 1010 CONTINUE
      DO 1030 NJ = 1,NJMAX
      NJM = NJ + NJMAX
      CNORM(NJM) = CCPAR(1,NJ,NJM)
      DO 1030 NP = 1, NJMAX2
      DO 1030 KC = 1, 3
      CCPAR(KC,NJ,NP) = CCPAR(KC,NJ,NP)/CNORM(NJM)
 1030 CONTINUE
 1005 CONTINUE
C
C     ******************************************************************
C
C     COMPUTE NONLINEAR COEFFICIENTS.
C
      IF (NONLIN .EQ. 0)  GO TO 402
      G1 = (GAMMA - 1.0) * 0.5
C
  170 DO 200 NJ = 1, NJMAX
      NJM = NJ + NJMAX
      DCOEF = 0.5 / CNORM(NJ)
      DO 200 NP = 1, NJMAX
      DO 200 NQ = 1, NJMAX
C
      CD1(NJ,NP,NQ) = (0.0,0.0)
      CD2(NJ,NP,NQ) = 0.0,0.0)
      CD3(NJ,NP,NQ) = (0.0,0.0)
      CD4(NJ,NP,NQ) = (0.0,0.0)
C
  244 DO 240 J = 2, 3
      DO 240 NC = 1, 4
      CALL AXIAL2(J,NC,NP,NQ,NJ,ZE,CRSLT)
      AXINT(NC,J) = CRSLT
  240 CONTINUE
```

```
C
      CD1(NJ,NP,NQ) = AXINT(1,2) + G1*AXINT(1,3)
      CD2(NJ,NP,NQ) = AXINT(2,2) + G1*AXINT(2,3)
      CD3(NJ,NP,NQ) = AXINT(3,2) + G1*AXINT(3,3)
      CD4(NJ,NP,NQ) = AXINT(4,2) + G1*AXINT(4,3)
C
      CD1(NJ,NP,NQ) = CD1(NJ,NP,NQ) * DCOEF * (1.0,-1.0)
      CD2(NJ,NP,NQ) = CD2(NJ,NP,NQ) * DCOEF * (1.0,1.0)
      CD3(NJ,NP,NQ) = CD3(NJ,NP,NQ) * DCOEF * (1.0,1.0)
      CD4(NJ,NP,NQ) = CD4(NJ,NP,NQ) * DCOEF * (1.0,-1.0)
C
  200 CONTINUE
C
C     ******************************************************************
C
C     CALCULATE COEFFICIENTS FOR EQUIVALENT REAL SYSTEM.
C
  402 DO 350 NJ = 1, NJMAX
      NEWJ = (2 * NJ) - 1
      NEWJ1 = NEWJ + 1
      DO 360 NP = 1,NJMAX2
      NEWP = (2 * NP) - 1
      NEWP1 = NEWP + 1
C
C     COEFFICIENTS OF LINEAR TERMS.
      IF (NP .GT. NJMAX) GO TO 1040
      CCR = REAL(CC(1,NJ,NP))
      CCI = AIMAG(CC(1,NJ,NP))
      C1(NEWJ,NEWP) = CCR
      C1(NEWJ,NEWP1) = -CCI
      C1(NEWJ1,NEWP) = CCI
      C1(NEWJ1,NEWP1) = CCR
 1040 CONTINUE
      DO 360 KC = 1,3
      CCR = REAL(CC(KC+1,NJ,NP))
      CCI = AIMAG(CC(KC+1,NJ,NP))
      C(KC,NEWJ,NEWP) = CCR
      C(KC,NEWJ,NEWP1) = -CCI
      C(KC,NEWJ1,NEWP) = CCI
      C(KC,NEWJ1,NEWP1) = CCR
  360 CONTINUE
C
C     COEFFICIENTS OF THE COMBUSTION TERM.
      DO 350 NP = 1, NJMAX
      NEWP = 2*NP - 1
      NEWP1 = NEWP + 1
      CCR = REAL(CC(5,NJ,NP))
      CCI = AIMAG(CC(5,NJ,NP))
      E(NEWJ,NEWP,1) = CCR
      E(NEWJ,NEWP,2) = - CCI
      E(NEWJ,NEWP1,1) = - CCI
      E(NEWJ,NEWP1,2) = - CCR
```

```
      E(NEWJ1,NEWP,1) = CCI
      E(NEWJ1,NEWP,2) = CCR
      E(NEWJ1,NEWP1,1) = CCR
      E(NEWJ1,NEWP1,2) = - CCI
  371 CONTINUE
C
C     COEFFICIENTS OF NONLINEAR TERMS.
      IF (NONLIN .EQ. 0) GO TO 350
      DO 370 NQ = 1, NJMAX
      NEWQ = (2 * NQ) - 1
      NEWQ1 = NEWQ + 1
      CD1R = REAL(CD1(NJ,NP,NQ))
      CD1I = AIMAG(CD1(NJ,NP,NQ))
      CD2R = REAL(CD2(NJ,NP,NQ))
      CD2I = AIMAG(CD2(NJ,NP,NQ))
      CD3R = REAL(CD3(NJ,NP,NQ))
      CD3I = AIMAG(CD3(NJ,NP,NQ))
      CD4R = REAL(CD4(NJ,NP,NQ))
      CD4I = AIMAG(CD4(NJ,NP,NQ))
      D(NEWJ,NEWP,NEWQ) = CD1R + CD2R + CD3R + CD4R
      D(NEWJ,NEWP,NEWQ1) = -CD1I + CD2I - CD3I + CD4I
      D(NEWJ,NEWP1,NEWQ) = -CD1I - CD2I + CD3I + CD4I
      D(NEWJ,NEWP1,NEWQ1) = -CD1R + CD2R + CD3R - CD4R
      D(NEWJ1,NEWP,NEWQ) = CD1I + CD2I + CD3I + CD4I
      D(NEWJ1,NEWP,NEWQ1) = CD1R - CD2R + CD3R - CD4R
      D(NEWJ1,NEWP1,NEWQ) = CD1R + CD2R - CD3R - CD4R
      D(NEWJ1,NEWP1,NEWQ1) = -CD1I + CD2I + CD3I - CD4I
  370 CONTINUE
  350 CONTINUE
C
      IF (NPRTKL .EQ. 0) GO TO 1035
      DO 1050 NJ = 1, NJMAX
      NJM = NJ + NJMAX
      NEWJ = 2*NJ - 1
      NEWJ1 = NEWJ + 1
      DO 1050 NP = 1, NJMAX2
      NEWP = 2*NP -1
      NEWP1 = NEWP + 1
      DO 830 KC = 1, 2
      CCR = REAL(CCPAR(KC+1,NJ,NP))
      CCI = AIMAG(CCPAR(KC+1,NJ,NP))
      CPAR(KC,NEWJ,NEWP) = CCR
      CPAR(KC,NEWJ,NEWP1) = -CCI
      CPAR(KC,NEWJ1,NEWP) = CCI
      CPAR(KC,NEWJ1,NEWP1) = CCR
  830 CONTINUE
      IF (NP .LE. NJMAX) GO TO 1050
      NEWP = NEWP - NJMAX2
      NEWP1 = NEWP + 1
      CCR = REAL(CCPAR(1,NJ,NP))
      CCI = AIMAG(CCPAR(1,NJ,NP))
      C1PAR(NEWJ,NEWP) = CCR
      C1PAR(NEWJ,NEWP1) = -CCI
      C1PAR(NEWJ1,NEWP) = CCI
      C1PAR(NEWJ1,NEWP1) = CCR
 1050 CONTINUE
 1035 CONTINUE
```

```
C
C     ****************************************************************
C
C     COMPUTE COEFFICIENTS FOR THE EQUATIONS WHICH ARE DECOUPLED
C     IN THE SECOND DERIVATIVES.
C
      DO 405 KC = 1, 6
      KMAX(KC) = 0
  405 CONTINUE
C
C     CALCULATE INVERSE OF THE MATRIX C1(I,J).
      JMAX = NJMAX
      NJMAX = 2 * NJMAX
      JMAX2 = NJMAX2
      NJMAX2 = 2 * NJMAX2
C
C
      V(1) = 1
      CALL GJR(C1,MAXMD2,MAXMD2,NJMAX,0,JC,V)
C
C     USE INVERSE TO CALCULATE DECOUPLED COEFFICIENTS.
C
C
C     LINEAR COEFFICIENTS.
      DO 430 NP = 1, NJMAX2
      DO 420 NJ = 1, NJMAX
      DO 420 KC = 1, 3
      TS(KC,NJ) = 0.0
      DO 420 K = 1, NJMAX
      TS(KC,NJ) = TS(KC,NJ) + C1(NJ,K) * C(KC,K,NP)
  420 CONTINUE
      DO 430 NJ = 1, NJMAX
      DO 430 KC = 1, 3
      C(KC,NJ,NP) = TS(KC,NJ)
      ABSVAL = ABS(C(KC,NJ,NP))
      IF (ABSVAL .GE. SM1)  KMAX(KC) = KMAX(KC) + 1
  430 CONTINUE
C
C     COEFFICIENTS OF THE COMBUSTION RESPONSE TERM.
      DO 720 NP = 1, NJMAX
      DO 725 NJ = 1, NJMAX
      TSR(1,NJ) = 0.0
      TSR(2,NJ) = 0.0
      DO 725 K = 1, NJMAX
      TSR(1,NJ) = TSR(1,NJ) + C1(NJ,K) * E(K,NP,1)
      TSR(2,NJ) = TSR(2,NJ) + C1(NJ,K) * E(K,NP,2)
  725 CONTINUE
      DO 730 NJ = 1, NJMAX
      E(NJ,NP,1) = TSR(1,NJ)
      ABSVAL = ABS(E(NJ,NP,1))
      IF (ABSVAL .GE. SM1) KMAX(4) = KMAX(4) + 1
      E(NJ,NP,2) = TSR(2,NJ)
      ABSVAL = ABS(E(NJ,NP,2))
      IF(ABSVAL .GT. SM1) KMAX(5) = KMAX(5) + 1
  730 CONTINUE
  720 CONTINUE
```

```
C
      IF (NPRTKL .EQ. 0) GO TO 1060
      KMAXPR(1) = 0
      KMAXPR(2) = 0
      V(1) = 1
      CALL GJR(C1PAR,MAXMD2,MAXMD2,NJMAX,0,JC,V)
      DO 1065 NP = 1, NJMAX2
      DO 1070 NJ = 1, NJMAX
      DO 1070 KC = 1, 2
      TSPAR(KC,NJ) = 0.0
      DO 1070 K = 1, NJMAX
      TSPAR(KC,NJ) = TSPAR(KC,NJ) + C1PAR(NJ,K)*CPAR(KC,K,NP)
 1070 CONTINUE
      DO 1065 NJ = 1,NJMAX
      DO 1065 KC = 1, 2
      CPAR(KC,NJ,NP) = TSPAR(KC,NJ)
      ABSVAL = ABS(CPAR(KC,NJ,NP))
      IF (ABSVAL .GE. SM1) KMAXPR(KC) = KMAXPR(KC) + 1
 1065 CONTINUE
 1060 CONTINUE
C
C     NONLINEAR COEFFICIENTS.
      IF (NONLIN .EQ. 0) GO TO 410
      DO 735 NP = 1, NJMAX
      DO 735 NQ = 1, NJMAX
      DO 440 NJ = 1, NJMAX
      TSQ(NJ) = 0.0
      DO 440 K = 1, NJMAX
      TSQ(NJ) = TSQ(NJ) + C1(NJ,K) * D(K,NP,NQ)
  440 CONTINUE
      DO 445 NJ = 1, NJMAX
      D(NJ,NP,NQ) = TSQ(NJ)
      ABSVAL = ABS(D(NJ,NP,NQ))
      IF (ABSVAL .GT. SM2) KMAX(6) = KMAX(6) + 1
  445 CONTINUE
  735 CONTINUE
  410 CONTINUE
C
C     ******************************************************************
C     OUTPUT.
C
      IF (NOUT .EQ. 2) GO TO 455
      WRITE (6,6001) TITLE
      WRITE (6,6002)  GAM, UE
      IF (NOZZLE .EQ. 0)  WRITE (6,6012)
      IF (NPRTKL .EQ. 0) WRITE (6,6022)
      IF (NPRTKL .EQ. 1) WRITE (6,6021) DIA, CM, FREQ,
     1                   TEMP, SP, RHOM, PARTKL
      WRITE (6,6004)
      DO 310 J = 1, JMAX
      WRITE (6,6003) NAME(J), J, L(J), B(J), YNOZ(J)
  310 CONTINUE
      IF (NONLIN .EQ. 0)  WRITE (6,6013)
```

```
C
C     OUTPUT OF LINEAR COEFFICIENTS.
      DO 320 KC = 1, 3
      NJS = 0
      NJF = 0
      KOUNTJ = 1
  758 NJS = NJF + 1
      NJF = 10 * KOUNTJ
      IF (NJF .GT. NJMAX) NJF = NJMAX
      NPS = 0
      NPF = 0
      KOUNTP = 1
  754 NPS = NPF + 1
      NPF = 10 * KOUNTP
      IF (NPF .GT. NJMAX2) NPF = NJMAX2
      IF (KC .EQ. 1)  WRITE (6,6005)
      IF (KC .EQ. 2)  WRITE (6,6006)
      IF (KC .EQ. 3)  WRITE (6,6007)
      WRITE (6,6008) (NP, NP = NPS, NPF)
      WRITE (6,6014)
      DO 750 NJ = NJS, NJF
      WRITE (6,6009) NJ, (C(KC,NJ,NP), NP = NPS, NPF)
  750 CONTINUE
      IF (NPF .EQ. NJMAX2) GO TO 752
      KOUNTP = KOUNTP + 1
      GO TO 754
  752 IF (NJF .EQ. NJMAX) GO TO 756
      KOUNTJ = KOUNTJ + 1
      GO TO 758
  756 CONTINUE
  320 CONTINUE
C
C     OUTPUT OF THE COMBUSTION RESPONSE TERM.
      DO 770 KC = 1, 2
      NJS = 0
      NJF = 0
      KOUNTJ = 1
  760 NJS = NJF + 1
      NJF = 10 * KOUNTJ
      IF (NJF .GT. NJMAX) NJF = NJMAX
      NPS = 0
      NPF = 0
      KOUNTP = 1
  762 NPS = NPF + 1
      NPF = 10 * KOUNTP
      IF (NPF .GT. NJMAX) NPF = NJMAX
      IF (KC .EQ. 1) WRITE (6,6019)
      IF (KC .EQ. 2) WRITE (6,6020)
      WRITE (6,6008) (NP, NP = NPS, NPF)
      WRITE (6,6014)
      DO 764 NJ = NJS, NJF
      WRITE (6,6009) NJ, (E(NJ,NP,KC), NP = NPS, NPF)
  764 CONTINUE
```

```
      IF (NPF .EQ. NJMAX) GO TO 766
      KOUNTP = KOUNTP + 1
      GO TO 762
  766 IF (NJF .EQ. NJMAX) GO TO 768
      KOUNTJ = KOUNTJ + 1
      GO TO 760
  768 CONTINUE
  770 CONTINUE
C
      IF (NPRTKL .EQ. 0) GO TO 835
      DO 1080 KC = 1, 2
      NJS = 0
      NJF = 0
      KOUNTJ = 1
C
 1072 NJS = NJF + 1
      NJF = 10*KOUNTJ
      IF (NJF .GT. NJMAX) NJF = NJMAX
      NPS = 0
      NPF = 0
      KOUNTP = 1
 1074 NPS = NPF+1
      NPF = 10*KOUNTP
      IF (NPF .GT.NJMAX2) NPF = NJMAX2
      WRITE (6,6023)
      WRITE (6,6008) (NP, NP = NPS,NPF)
      WRITE (6,6014)
      DO 1076 NJ = NJS,NJF
      WRITE (6,6009) NJ, (CPAR(KC,NJ,NP),NP = NPS,NPF)
 1076 CONTINUE
      IF (NPF .EQ. NJMAX2) GO TO 1078
      KOUNTP = KOUNTP + 1
      GO TO 1074
 1078 IF (NJF .EQ. NJMAX) GO TO 1080
      KOUNTJ = KOUNTJ + 1
      GO TO 1072
 1080 CONTINUE
  835 CONTINUE
C     OUTPUT OF NONLINEAR COEFFICIENTS.
      IF (NONLIN .EQ. 0)  GO TO 452
      DO 400 NJ = 1, NJMAX
      NPS = 0
      NPF = 0
      KOUNTP = 1
  780 NPS = NPF + 1
      NPF = 10 * KOUNTP
      IF (NPF .GT. NJMAX) NPF = NJMAX
      NQS = 0
      NQF = 0
      KOUNTQ = 1
  776 NQS = NQF + 1
      NQF = 10 * KOUNTQ
```

```
      IF (NQF .GT. NJMAX) NQF = NJMAX
      WRITE (6,6010) NJ
      WRITE (6,6011) (NQ, NQ = NQS, NQF)
      WRITE (6,6015)
      DO 772 NP = NPS, NPF
      WRITE (6,6009) NP, (D(NJ,NP,NQ), NQ = NQS, NQF)
  772 CONTINUE
  771 CONTINUE
      IF (NQF .EQ. NJMAX) GO TO 774
      KOUNTQ = KOUNTQ + 1
      GO TO 776
  774 IF (NPF .EQ. NJMAX) GO TO 778
      KOUNTP = KOUNTP + 1
      GO TO 780
  778 CONTINUE
  400 CONTINUE
  452 IF (NOUT .EQ. 0) GO TO 4
C
C     WRITE COEFFICIENTS ON FILE.
C
  455 WRITE (9,7001) GAMMA, UE, ZE, NJMAX, NPRTKL
      IF (NPRTKL .EQ. 1) WRITE (9,7007) DIA, RHOM, SP, TEMP, FREQ,
     1                                                  PARTKL, CM
C
      DO 450 J = 1, JMAX
      WRITE (9,7002)  J, L(J), NAME(J)
  450 CONTINUE
C
      DO 457 J = 1, JMAX
      WRITE (9,7006) J, YNOZ(J), B(J)
  457 CONTINUE
C
      DO 460 KC = 1, 3
      WRITE (9,7003) KMAX(KC)
      DO 460 NJ = 1, NJMAX
      DO 460 NP = 1, NJMAX2
      ABSVAL = ABS(C(KC,NJ,NP))
      IF (ABSVAL .GE. SM1)  WRITE (9,7004)  NJ, NP, C(KC,NJ,NP)
  460 CONTINUE
C
      DO 820 KC = 4, 5
      WRITE (9,7003) KMAX(KC)
      KCMIN3 = KC - 3
      DO 820 NJ = 1, NJMAX
      DO 820 NP = 1, NJMAX
      ABSVAL = ABS(E(NJ,NP,KCMIN3))
      IF (ABSVAL .GT. SM1) WRITE (9,7004) NJ, NP, E(NJ,NP,KCMIN3)
  820 CONTINUE
C
```

```
      DO 1082 KC = 1, 2
      WRITE (9,7003) KMAXPR(KC)
      DO 1082 NJ = 1, NJMAX
      DO 1082 NP = 1, NJMAX2
      ABSVAL = ABS(CPAR(KC,NJ,NP))
      IF (ABSVAL .GE. SM1) WRITE (9,7004)NJ,NP,CPAR(KC,NJ,NP)
 1082 CONTINUE
C
      WRITE (9,7003) KMAX(6)
      IF (NONLIN .EQ. 0)  GO TO 4
      DO 470 NJ = 1, NJMAX
      DO 470 NP = 1, NJMAX
      DO 470 NQ = 1, NJMAX
      ABSVAL = ABS(D(NJ,NP,NQ))
      IF (ABSVAL .GE. SM2)  WRITE (9,7005) NJ, NP, NQ, D(NJ,NP,NQ)
  470 CONTINUE
      GO TO 4
C
  600 CONTINUE
C
C     ****************************************************************
C
C     FORMAT SPECIFICATIONS.
 5000 FORMAT (7A10)
 5001 FORMAT (2F10.0,I5)
 5002 FORMAT (2I5,1X,A4)
 5003 FORMAT (I5,2F10.0)
 5004 FORMAT (6I5)
 5005 FORMAT (2F10.0)
 5006 FORMAT (6F10.0)
 6001 FORMAT (1H1,1X,7A10//)
 6002 FORMAT (2X,8HGAMMA = ,F8.5,5X,4HUE =,F6.4,//)
 6003 FORMAT (2X,A4,2I5,4F10.5/)
 6004 FORMAT (2X////2X,14HNAME     J    L,6X,3HEPS,7X,3HETA,
     1        8X,2HYR,7X,2HYI//)
 6005 FORMAT (1H1,45H  DECOUPLED COEFFICIENT OF B(P):      C(1,J,P)///)
 6006 FORMAT (1H1,44H  DECOUPLED COEFFICIENT OF THE DERIVATIVE OF,
     1        6H B(P):,5X,8HC(2,J,P)///)
 6007 FORMAT (1H1,36H  DECOUPLED COEFFICIENT OF THE TERM,,
     1        15H MULTIPLYING K:,5X,8HC(3,J,P)///)
 6008 FORMAT (7X,1HP,I8,9I12)
 6009 FORMAT (2X//2X,I3,3X,10F12.6)
 6010 FORMAT (1H1,47HDECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION,
     1        7H FOR B(,I2,1H)///)
 6011 FORMAT (7X,1HQ,I8,9I12)
 6012 FORMAT (2X,20HQUASI-STEADY NOZZLE./)
 6013 FORMAT (2X//2X,24HLINEAR COEFFICIENTS ONLY)
 6014 FORMAT (4X,1HJ)
 6015 FORMAT (4X,1HP)
 6019 FORMAT (1H1,40H  DECOUPLED COEFFICIENT OF THE REAL PART,
     1        24H OF THE COMBUSTION TERM:,5X,8HE(J,P,1)///)
```

```
6020 FORMAT (1H1,45H  DECOUPLED COEFFICIENT OF THE IMAGINARY PART,
     1       24H OF THE COMBUSTION TERM:,5X,8HE(J,P,2)///)
6021 FORMAT (///,10X,27HPARTICLE DIA (IN MICRONS) = ,F5.2,10X,
     1       4HCM =,F6.4,10X,18HFREQ (IN HERTZ) = ,F6.1,//,
     2       10X,26HCHAMBER TEMP (IN DEG K) = ,F6.1,10X,4HSP =,
     3       F6.4,10X,27HRHOM (IN KG/CUBIC METER) = ,F6.1,//,10X,
     4       30HPARTICLE DRAG COEFFICIENT, K =,F8.4,////)
6022 FORMAT (2X,22HPARTICLES NOT PRESENT.//)
6023 FORMAT (1H1,39HCOEFFICIENTS IN THE PARTICLE EQUATIONS:,
     1       12H   CPAR(J,P)///)
7001 FORMAT (3F10.5,3I5)
7002 FORMAT (2I5,1X,A4)
7003 FORMAT (I5)
7004 FORMAT (2I5,F15.8)
7005 FORMAT (3I5,F15.8)
7006 FORMAT (I5,4F12.8)
7007 FORMAT (7F15.8)
     END
```

```
      SUBROUTINE AXIAL1(NOPT,NP,NJ,UE,ZE,RESULT)
C
C
C     THIS SUBROUTINE CALCULATES THE INTEGRAL OVER THE INTERVAL
C     (0,ZE) OF THE FOLLOWING FUNCTIONS ACCORDING TO THE VALUE
C     OF NOPT
C
C     NOPT = 1         Z(NP) * ZC(NJ)
C     NOPT = 2         ZPP(NP) * ZC(NJ)
C     NOPT = 3         UP * Z(NP) * ZC(NJ)
C     NOPT = 4         U * ZP(NP) * ZC(NJ)
C
C     IN THE ABOVE EQUATIONS:
C     Z(NP) IS THE AXIAL ACOUSTIC EIGENFUNCTION OF INDEX NP.
C     Z(NJ) IS THE AXIAL ACOUSTIC EIGENFUNCTION OF INDEX NJ.
C     ZC IS THE COMPLEX CONJUGATE OF THE AXIAL EIGENFUNCTION.
C     ZP AND ZPP ARE THE FIRST AND SECOND DERIVATIVES OF THE
C     AXIAL EIGENFUNCTIONS RESPECTIVELY.
C     U IS THE STEADY STATE VELOCITY DISTRIBUTION AND UP IS ITS
C     AXIAL DERIVATIVE.
C     THE VELOCITY DISTRIBUTION IS COMPUTED BY THE SUBROUTINE UBAR.
C
C
      REAL      MAG
      COMPLEX   CI, CZE, BP, BJ, T1, T2, CH, F1, F2, F3, CZ, ARG,
     1          S1, S2, S3, RESULT, FUNCT(500), B(6), CCOSH, CSINH
      COMMON    B
C
      MAXMD = 6
      CI = (0.0,1.0)
      CZE = CMPLX(ZE,0.0)
      BP = B(NP)
      BJ = CONJG(B(NJ))
C
      IF (NOPT .GT. 2)  GO TO 50
C     CALCULATE INTEGRALS BY MEANS OF ANALYTICAL EXPRESSIONS FOR
C     NOPT = 1 AND NOPT = 2.
      ARG = (BP + BJ) * CI
      MAG = CABS(ARG)
      IF (MAG) 20, 25, 20
   20 T1 = CSINH(ARG*CZE)/ARG
      GO TO 30
   25 T1 = CZE
   30 ARG = (BP - BJ) * CI
      MAG = CABS(ARG)
      IF (MAG) 35, 40, 35
   35 T2 = CSINH(ARG*CZE)/ARG
      GO TO 45
   40 T2 = CZE
   45 RESULT = (T1 + T2) * (0.5,0.0)
      IF (NOPT .EQ. 2)  RESULT = -B(NP) * B(NP) * RESULT
      GO TO 100
```

```
C
C     NUMERICAL EVALUATION OF INTEGRALS FOR NOPT = 3 AND NOPT = 4.
C
C     COMPUTE STEP SIZE FOR SIMPSON INTEGRATION.
   50 N = 50
      RN = N
      RESULT = (0.0,0.0)
      NOPT2 = NOPT - 2
C
       H = ZE/RN
      Z0 = 0.0
      NP1 = N + 1
      CH = CMPLX(H,0.0)
C
C     COMPUTE INTEGRANDS.
      DO 60 I = 1, NP1
      STEP = I - 1
      Z = (STEP * H) + Z0
      CZ = CMPLX(Z,0.0)
      ARG = CI * BP
      IF (NOPT2 .EQ. 2) GO TO 120
      CALL UBAR(2,UE,ZE,Z,F)
      F2 = CCOSH(ARG*CZ)
      GO TO 170
  120 CALL UBAR(1,UE,ZE,Z,F)
      F2 = ARG * CSINH(ARG*CZ)
  170 CONTINUE
      F1 = CMPLX(F,0.0)
      ARG = CI * BJ
      F3 = CCOSH(ARG*CZ)
      FUNCT(I) = F1 * F2 * F3
   60 CONTINUE
C
C     PERFORM SIMPSON INTEGRATION.
      NM1 = N - 1
      S1 = FUNCT(1) + FUNCT(NP1)
      S2 = (0.0,0.0)
      S3 = (0.0,0.0)
      DO 70 I = 2, N, 2
      S2 = S2 + FUNCT(I)
   70 CONTINUE
      DO 80 I = 3, NM1, 2
      S3 = S3 + FUNCT(I)
   80 CONTINUE
      RESULT = RESULT +
     1         CH * (S1 + (4.0,0.0)*S2 + (2.0,0.0)*S3)/(3.0,0.0)
C
  100 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE AXIAL2(NOPT,NCONJ,NP,NQ,NJ,ZE,RESULT)
C
C
C     THIS SUBROUTINE CALCULATES THE INTEGRAL OVER THE INTERVAL
C     (O,ZE) OF THE FOLLOWING FUNCTIONS ACCORDING TO THE VALUES
C     OF NOPT AND NCONJ
C
C     FOR NCONJ = 1 AND
C     NOPT = 1      Z(NP) * Z(NQ) * ZC(NJ)
C     NOPT = 2      ZP(NP) * ZP(NQ) * ZC(NJ)
C     NOPT = 3      ZPP(NP) * Z(NQ) * ZC(NJ)
C     NOPT = 4      ZP(NP) * Z(NQ) * ZC(NJ)
C
C     FOR NCONJ = 2 AND
C     NOPT = 1      Z(NP) * ZC(NQ) * ZC(NJ)
C     NOPT = 2      ZP(NP) * ZPC(NQ) * ZC(NJ)
C     NOPT = 3      ZPP(NP) * ZC(NQ) * ZC(NJ)
C
C     FOR NCONJ = 3 AND
C     NOPT = 1      ZC(NP) * Z(NQ) * ZC(NJ)
C     NOPT = 2      ZPC(NP) * ZP(NQ) * ZC(NJ)
C     NOPT = 3      ZPPC(NP) * Z(NQ) * ZC(NJ)
C
C     FOR NCONJ = 4 AND
C     NOPT = 1      ZC(NP) * ZC(NQ) * ZC(NJ)
C     NOPT = 2      ZPC(NP) * ZPC(NQ) * ZC(NJ)
C     NOPT = 3      ZPPC(NP) * ZC(NQ) * ZC(NJ)
C
C     IN THE ABOVE EQUATIONS:
C     Z(NP), Z(NQ), AND Z(NJ) ARE THE AXIAL ACOUSTIC EIGENFUNCTIONS
C     AND NP, NQ, AND NJ ARE THEIR INDICES.
C     ZP IS THE FIRST DERIVATIVE OF THE AXIAL EIGENFUNCTIONS.
C     ZPP IS THE SECOND DERIVATIVE OF THE AXIAL EIGENFUNCTIONS.
C     ZC AND ZPC ARE COMPLEX CONJUGATES OF Z AND ZP RESPECTIVELY.
C
C
      REAL      MAG
      COMPLEX   CI, CF, CZE, BP, BQ, BJ, SUM, RESULT,
     1          ARG(4), FUNCT(4), B(6), CCOSH, CSINH
      COMMON    B
      MAXMD = 6
C
C     CALCULATE INTEGRALS BY MEANS OF ANALYTICAL EXPRESSIONS.
      CI = (0.0,1.0)
      CF = (0.25,0.0)
      CZE = CMPLX(ZE,0.0)
      BP = B(NP)
      BQ = B(NQ)
      BJ = CONJG(B(NJ))
      IF ((NCONJ .EQ. 2) .OR. (NCONJ .EQ. 4))  BQ = CONJG(BQ)
      IF (NCONJ .GT. 2)  BP = CONJG(BP)
```

```
      ARG(1) = (BP + BQ + BJ) * CI
      ARG(2) = (BP + BQ - BJ) * CI
      ARG(3) = (BP - BQ + BJ) * CI
      ARG(4) = (BP - BQ - BJ) * CI
      DO 10 J = 1,4
      MAG = CABS(ARG(J))
      IF (MAG) 12, 15, 12
   12 FUNCT(J) = CSINH(ARG(J)*CZE)/ARG(J)
      IF (NOPT .EQ. 4) FUNCT(J) = (CCOSH(ARG(J)*CZE) - 1.0)/ARG(J)
      GO TO 10
   15 FUNCT(J) = CZE
      IF (NOPT .EQ. 4) FUNCT(J) = 0.0
   10 CONTINUE
      IF (NOPT .EQ. 2)  GO TO 30
      SUM = FUNCT(1) + FUNCT(2) + FUNCT(3) + FUNCT(4)
      RESULT = CF * SUM
      IF (NOPT .EQ. 3)  RESULT = -BP * BP * RESULT
      IF (NOPT .EQ. 4) RESULT = CI * BP * RESULT
      GO TO 50
   30 SUM = FUNCT(1) + FUNCT(2) - FUNCT(3) - FUNCT(4)
      RESULT = -CF * BP * BQ * SUM
   50 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE EIGVAL(L,SMN,GAMMA,ZE,YAMPL,YPHASE,RESULT)
C
      COMPLEX    RESULT
      COMMON  /BLK1/ GSQ, ABSQ, ALBET, SMNSQ
C
C     ****************************************************************
C
C     THIS SUBROUTINE COMPUTES THE COMPLEX AXIAL ACOUSTIC EIGENVALUES
C     FOR A CYLINDRICAL CHAMBER WITH A NOZZLE AND STORES THEM IN
C     RESULT.
C     THE EIGENVALUES ARE COMPUTED BY MEANS OF NEWTONS METHOD.
C
C     THE INPUT PARAMETERS ARE AS FOLLOWS
C     L IS THE AXIAL MODE NUMBER.
C     SMN IS THE DIMENSIONLESS ACOUSTIC FREQUENCY.
C     GAMMA IS THE SPECIFIC HEAT RATIO.
C     ZE IS THE DIMENSIONLESS LENGTH OF THE CHAMBER.
C     YAMPL IS THE NOZZLE AMPLITUDE FACTOR.
C     YPHASE IS THE NOZZLE PHASE SHIFT IN DEGREES.
C
C     ****************************************************************
C
      PI = 3.1415926536
      ERR = 0.0000001
C
      IF (YAMPL) 5, 60, 5
C     CALCULATE CONSTANTS.
    5 PHASE = YPHASE * PI/180.0
      ALPHA = YAMPL * COS(PHASE)
      BETA  = YAMPL * SIN(PHASE)
      GSQ = GAMMA * GAMMA
      ABSQ = (ALPHA * ALPHA) - (BETA * BETA)
      ALBET = ALPHA * BETA
      SMNSQ = SMN * SMN
C
C     ASSIGN INITIAL GUESS FOR EIGENVALUE.
      IF (L .EQ. 0)  GO TO 45
      RL = L
      PHI = PI/2.0 + PHASE
      XM = RL * PI/ZE
      A = YAMPL/ZE
      XO = XM + A*COS(PHI)
      YO = A*SIN(PHI)
      GO TO 47
   45 PHI = PI/4.0 + 0.5*PHASE
      A = YAMPL * 10.0/ZE
      XO = A * COS(PHI)
      YO = A * SIN(PHI)
```

```
C
C     ITERATION USING NEWTONS METHOD FOR A SYSTEM OF TWO EQUATIONS
C     IN TWO UNKNOWNS.
   47 L1 = 0
      X = X0
      Y = Y0
   40 CALL FCNS(X,Y,ZE,F,G,FX,FY,GX,GY)
      IF (L1 .EQ. 40)  GO TO 50
      RJFG = (FX * GY) - (GX * FY)
      IF (RJFG) 20, 30, 20
   20 DELTAX = (-F * GY   +   G * FY)/RJFG
      DELTAY = (-G * FX   +   F * GX)/RJFG
      L1 = L1 + 1
      X = X + DELTAX
      Y = Y + DELTAY
C
C     TEST FOR CONVERGENCE.
      IF (ABS(DELTAX) .GE. ERR .OR. ABS(DELTAY) .GE. ERR)  GO TO 40
      GO TO 10
C
C     WARNING MESSAGES
   30 WRITE (6,6005)
      GO TO 10
   50 WRITE (6,6006)
      GO TO 10
C
C     CASE OF HARD WALL (YAMPL = 0).
   60 RL = L
      X = RL * PI/ZE
      Y = 0.0
C
   10 RESULT = CMPLX(X,Y)
C
C     FORMAT SPECIFICATIONS.
 6005 FORMAT (2X//2X,16HJACOBIAN IS ZERO//)
 6006 FORMAT (2X//2X,35HFAILED TO CONVERGE IN 40 ITERATIONS//)
      RETURN
      END
```

```
      SUBROUTINE FCNS(X,Y,ZE,F,G,FX,FY,GX,GY)
C
C     THIS SUBROUTINE COMPUTES THE FUNCTIONS F(X,Y) AND G(X,Y)
C     AND THEIR PARTIAL DERIVATIVES WITH RESPECT TO X AND Y.
C
      COMMON  /BLK1/ GSQ, ABSQ, ALBET, SMNSQ
C
C     COMPUTE THE TRIGONOMETRIC FUNCTIONS, THE HYPERBOLIC FUNCTIONS
C     AND THEIR SQUARES.
C
      I = 1
      ARGX = ZE * X
      ARGY = ZE * Y
   10 SX = SIN(ARGX)
      CX = COS(ARGX)
      SHY = SINH(ARGY)
      CHY = COSH(ARGY)
      IF (I .EQ. 2)  GO TO 20
      SXSQ = SX * SX
      CXSQ = CX * CX
      SHYSQ = SHY * SHY
      CHYSQ = CHY * CHY
      ARGX = 2.0 * ARGX
      ARGY = 2.0 * ARGY
      I = 2
      GO TO 10
C
C     COMPUTE TRANSCENDENTAL FUNCTIONS AND THEIR DERIVATIVES
C
   20 FF = (SXSQ * CHYSQ) - (CXSQ * SHYSQ)
      GG = (CXSQ * CHYSQ) - (SXSQ * SHYSQ)
      HH = 0.25 * SX * SHY
      FFX = ZE * SX * CHY
      GGY = ZE * CX * SHY
      FFY = -GGY
      GGX = -FFX
      HHX = 0.5 * GGY
      HHY = 0.5 * FFX
C
C     COMPUTE FACTORS
      XYSQ = (X * X) - (Y * Y)
      XY = X * Y
      SMNXY = SMNSQ + XYSQ
      F1 = (ABSQ * SMNXY) - (4.0 * ALBET * XY)
      F2 = (ALBET * SMNXY) + (ABSQ * XY)
      G1 = (ABSQ * SMNXY) + (4.0 * ALBET * XY)
      FX1 = (2.0 * X * ABSQ) - (4.0 * ALBET * Y)
      FX2 = (2.0 * X * ALBET) + (ABSQ * Y)
      FY1 = (-2.0 * Y * ABSQ) - (4.0 * ALBET * X)
      FY2 = (-2.0 * Y * ALBET) + (ABSQ * X)
      GX1 = (2.0 * X * ABSQ) + (4.0 * ALBET * Y)
      GY1 = (-2.0 * Y * ABSQ) + (4.0 * ALBET * X)
```

```
C
C     COMPUTE F(X,Y) AND G(X,Y)
C
      F = (XYSQ * FF) - (4.0 * XY * HH)
     1    + GSQ * ((F1 * GG) + (4.0 * F2 * HH))
      G = (XYSQ * HH) + (XY * FF)
     1    + GSQ * ((F2 * GG) - (G1 * HH))
C
C     COMPUTE THE PARTIAL DERIVATIVES OF F AND G
C
      FX = (2.0 * X * FF) + (XYSQ * FFX)
     1    -4.0 * ((Y * HH) + (XY * HHX))
     2    + GSQ * ((FX1 * GG) + (F1 * GGX)
     3    + (4.0 * FX2 * HH) + (4.0 * F2 * HHX))
      FY = (-2.0 * Y * FF) + (XYSQ * FFY)
     1    -4.0 * ((X * HH) + (XY * HHY))
     2    + GSQ * ((FY1 * GG) + (F1 * GGY)
     3    + (4.0 * FY2 * HH) + (4.0 * F2 * HHY))
      GX = (2.0 * X * HH) + (XYSQ * HHX)
     1    + (Y * FF) + (XY * FFX)
     2    + GSQ * ((FX2 * GG) + (F2 * GGX)
     3    -(GX1 * HH) - (G1 * HHX))
      GY = (-2.0 * Y * HH) + (XYSQ * HHY)
     1    + (X * FF) + (XY * FFY)
     2    + GSQ * ((FY2 * GG) + (F2 * GGY)
     3    -(GY1 * HH) - (G1 * HHY))
      RETURN
      END
```

```
      SUBROUTINE GJR(A,NC,NR,N,MC,JC,V)
      DIMENSION A(NC,NR), JC(NR), V(2)
      IW=V(1)
      M=1
      S=1.
      L=N+(MC-N)*(IW/4)
      KD=2-MOD(IW/2,2)
      IF(KD.EQ.1) V(2)=0.
      KI=2-MOD(IW,2)
      IF (KI .EQ. 2) GO TO 20
    5 DO 10 I=1,N
   10 JC(I)=I
   20 DO 91 I=1,N
      IF (KI .EQ. 1) GO TO 22
   21 M=I
   22 IF(I.EQ.N) GO TO 60
      X=-1.
      DO 30 J=I,N
      IF(X.GT.ABS(A(J,I))) GO TO 30
      X=ABS(A(J,I))
      K=J
   30 CONTINUE
      IF(K.EQ.I) GO TO 60
      S=-S
      V(1)=-V(1)
      IF (KI .EQ. 2) GO TO 40
   35 MU=JC(I)
      JC(I)=JC(K)
      JC(K)=MU
   40 DO 50 J=M,L
      X=A(I,J)
      A(I,J)=A(K,J)
   50 A(K,J)=X
   60 IF(ABS(A(I,I)).GT.0.) GO TO 70
      IF(KD.EQ.1) V(1)=0.
      JC(1)=I-1
      WRITE (6,1000)
 1000 FORMAT (1X,29HTROUBLE WITH MATRIX INVERSION)
      WRITE (6,1001) JC(1)
 1001 FORMAT (1X,6HJC(1)=,I4)
      STOP
   70 IF (KD .EQ. 2) GO TO 72
   71 IF(A(I,I).LT.0.) S=-S
      V(2)=V(2)+ALOG(ABS(A(I,I)))
   72 X=A(I,I)
      A(I,I)=1.
      DO 80 J=M,L
      A(I,J)=A(I,J)/X
   80 CONTINUE
```

```
      DO 91 K=1,N
      IF(K.EQ.I) GO TO 91
      X=A(K,I)
      A(K,I)=0.
      DO 90 J=M,L
      A(K,J)=A(K,J)-X*A(I,J)
   90 CONTINUE
   91 CONTINUE
      IF (KI .EQ. 2) GO TO 140
   95 DO 130 J=1,N
      IF(JC(J).EQ.J) GO TO 130
      JJ=J+1
      DO 100 I=JJ,N
      IF(JC(I).EQ.J) GO TO 110
  100 CONTINUE
  110 JC(I)=JC(J)
      DO 120 K=1,N
      X=A(K,I)
      A(K,I)=A(K,J)
  120 A(K,J)=X
  130 CONTINUE
  140 JC(1)=N
      IF(KD.EQ.1) V(1)=S
      RETURN
      END
```

```
      SUBROUTINE UBAR(NOPT,UE,ZE,Z,RESULT)
C
C     THIS SUBROUTINE CALCULATES THE STEADY STATE VELOCITY DISTRIBUTION.
C     UE IS THE EXIT MACH NUMBER.
C     ZE IS THE DIMENSIONLESS LENGTH.
C     Z IS THE AXIAL COORDINATE.
C
C     IF NOPT = 1 THE DISTRIBUTION IS CALCULATED.
C     IF NOPT = 2 THE DERIVATIVE IS CALCULATED.
C
C
      IF (NOPT .EQ. 1) RESULT = UE * Z/ZE
      IF (NOPT .EQ. 2) RESULT = UE/ZE
      RETURN
      END


      COMPLEX FUNCTION CCOSH(X)
      COMPLEX X
      CCOSH = 0.5 * (CEXP(X) + CEXP(-X))
      RETURN
      END


      COMPLEX FUNCTION CSINH(X)
      COMPLEX X
      CSINH = 0.5 * (CEXP(X) - CEXP(-X))
      RETURN
      END
```

3.2 PROGRAM SOLID2

In conjunction with Program SOLID1, Program SOLID2 calculates the non-linear stability characteristics of a cylindrical combustor according to the approximate theory developed in Volume I. Using the coefficients computed by SOLID1, this program integrates the system of differential equations for the mode amplitudes (i.e., Equations (22) and (23)) and computes the time-history of a pressure disturbance in the motor.

Program Structure. This program performs the following operations: (1) reads the input data, (2) calculates the initial values, (3) numerically integrates the differential equations, and (4) plots and prints the solutions.

The inputs to the program include the data generated by SOLID1, the combustion response parameters, various control numbers, plotting information and a description of the initial disturbance. The data from SOLID1 is read first and then printed out. Next the space dependent coefficients appearing in the series expansions for Φ_t and Φ_x are computed and printed. These coefficients are calculated by subroutine PHICFS for use in the computation of the pressure perturbation. The remaining input data is then read, and following program execution, control is returned to this point so that several cases may be run for a given set of coefficients generated by SOLID1.

The initial disturbance may be specified as a purely fundamental mode (1L) disturbance or as an arbitrary combination of modes. The number of modes for which initial disturbances are specified is NTERMS, and for each of those modes the amplitudes AST and ACT are specified. Thus the initial waveform of the real part of the amplitude for each specified mode is given by:

$$B_{2j-1}(t) = AST \sin(\omega_j t) + ACT \cos(\omega_j t)$$

where B_{2j-1} is the real part of the amplitude of the j^{th} mode and ω_j is the acoustic frequency of the j^{th} mode. The amplitudes, B_{2j}, of the imaginary parts are calculated in the program by requiring the individual modes to satisfy the nozzle admittance condition. The initial values of the amplitudes of those modes whose initial disturbance is specified to be non-zero are then printed out. It must be noted that the specified inputs AST and ACT refer to the amplitude of the velocity potential and not to the pressure amplitude.

After the starting values are calculated, numerical integration of the system of differential equations is performed using a fourth-order Runge-Kutta scheme with the specified step size. A step size of about 0.025 is recommended.

Subroutine RHS is used to compute the differential increments needed in the Runge-Kutta integration. From the computed amplitude functions and the coefficients from the subroutine PHICFS the pressure perturbation at each step is calculated using the subroutine PRSVEL. The computed value of the pressure perturbation is then printed out if the pressure history printout is desired.

If plotting of the pressure history is required, subroutine GRAPHS is used to obtain CALCOMP plots for the desired pressure waveforms.

The program then computes the dimensional frequency of oscillation and the pressure growth rate at the end of each oscillation cycle using the subroutine GRØWTH.

Description of Input. The input data required to run this program consists of three parts: (1) the control numbers NØUTCF and NHISTR which determine the extent of desired printed output, as explained later in this section, (2) the parameters and coefficients generated by SOLID1, and (3) data describing the case to be run. For each case, the following information must be provided: the combustion response parameters, description of the initial disturbance, various control numbers and plotting information.

A list of necessary input data is described below. The description of format for integer and real constants, given previously for SOLID1, apply here also; i.e., each integer is allotted five columns and each real constant is allotted a field of ten columns.

The three parts of the input are:

(1) The control numbers, NØUTCF and NHISTR.

(2) The coefficients from Program SOLID1.

(3) The data deck.

The first card gives the control numbers, NØUTCF and NHISTR.

NØUTCF determines printout of coefficients:

If NØUTCF = 0 coefficients are not printed out.

If NØUTCF = 1 only linear coefficients are printed out.

If NØUTCF = 2 all coefficients are printed out.

NHISTR determines if pressure history is to be printed:

If NHISTR = 0 printed

If NHISTR = 1 not printed.

The coefficients are obtained from program SOLID1 by putting NØUT = 1 or NØUT = 2 in that program, thereby writing the coefficients into a disk.

This disk has been given the device number 9.

The data deck consists of the following cards:

First card: Title of the case.

Second card: H, TSTART, TQUIT, FREQ, BCØMB

H is the integration step size.

TSTART is the time at which output starts.

TQUIT is the time at which computations are terminated.

FREQ is the motor frequency (in pure gas) in Hertz.

BCØMB is the combustion response nonlinearity factor.

Third card: A2PARA, B2PARA, EN, ØMEGA

A2PARA and B2PARA are the combustion parameters in the A-B model.

EN is the pressure exponent in the burning rate law.

ØMEGA is the frequency nondimensionalized by the square of the steady-state burning rate.

Fourth card: NLØC, NTERMS, NØUT, NCØMB, NNPRT

NLØC determines the location of the wall pressure maxima and minima:

If NLØC = 1 location is x = 0.0

If NLØC = 2 location is x = 1.0

If NLØC = 3 location is x = 0.5

NTERMS is the number of terms given initial values.

NØUT is the output control number.

If NØUT = 0 printed output only.

If NØUT > 0 both printed and plotted output;

If NØUT = 1 plot of pressure at x = 0.0 only.

If NØUT = 2 plot of pressure at x = 0.0 and x = 1.0

If NØUT = 3 plot of pressure at x = 0.0, 1.0 and 0.5.

NCØMB determines if combustion nonlinearities are considered:

If NCØMB = 0 neglected.

If NCØMB = 1 included.

NNPRT determines if nonlinear particle damping is considered:

If NNPRT = 0 not considered.

If NNPRT = 1 considered.

Next card (necessary only if NNPRT = 1): REFPRS, CPGAS, CNLP

REFPRS is the chamber pressure, in psi.

CPGAS is the specific heat at constant pressure of the gas phase in cal/gm-deg K.

CNLP is the constant C in the amplitude dependence of the nonlinear particle drag.

Next card (necessary only if plots are required): YHI, YLAB, ITICY

YHI is the maximum ordinate for pressure plots.

Note: the ordinate scales for pressure and amplitude plots are symmetric about zero.

YLAB is the interval for ordinate labeling for above plots.

ITICY is the number of ordinate tick marks for above plots.

Note: ITICY should be negative for pressure and amplitude plots to obtain centerline.

Next card (necessary only if plots are required): MDPLØT

MDPLØT determines if plots of individual modes are required:

If plot of J^{th} mode is required, punch "1" in the $5 \times J^{th}$ column.

If plot of J^{th} mode is not required, punch "0" in the $5 \times J^{th}$ column.

Next card (necessary only if plot of any mode amplitude is required): YHIMD, YLABMD, ITICMD

YHIMD is the maximum ordinate.

YLABMD is the interval for ordinate labelling.

ITICMD is the number of ordinate tick marks for mode plots.

Note: ITICMD should be negative to obtain centerline.

Remaining cards (NTERMS in number): J, AST, ACT

AST is the amplitude of the sine term of the J^{th} mode.

ACT is the amplitude of the cosine term of the J^{th} mode.

It must be noted that AST and ACT are the amplitudes of the mode-amplitude functions and not the pressure. If the initial pressure disturbance is given for only one mode (say, the j^{th} longitudinal mode) then the values of AST and ACT which yield the desired initial pressure disturbance are given as follows:

$$ACT = 0.0, \qquad AST = \frac{1 - \sqrt{1 + \frac{2|p'|}{\bar{\gamma}}}}{\omega_j}$$

where $|p'|$ is the desired initial head-end pressure amplitude, $\bar{\gamma}$ is the specific heat ratio of the gas-particle mixture given by Equation (105), and ω_j is the acoustic frequency of the j^{th} longitudinal mode given by

$$\omega_j = j\pi \frac{\bar{\gamma}}{\gamma(1+C_m)}$$

If no particles are present, $\bar{\gamma} = \gamma$ and $\omega_j = j\pi$. The above equation for AST was derived from the momentum equation (i.e., Equation (24)).

Description of the Subroutines. The various subroutines utilized in program SOLID2 are described below:

SUBRØUTINE PHICFS(NP, Z, CT, CZ). This subroutine computes the space-dependent coefficients appearing in the NP^{th} mode of the series expansion for Φ_t and Φ_x. Z is the axial location (i.e., x) at which these coefficients are needed, and CT and CZ are these coefficients. CT is just the eigenfunction for the NP^{th} mode and CZ is the axial derivative of the eigenfunction (both evaluated at the location Z). The eigenvalues B are supplied through the labeled common block BLK2.

SUBRØUTINE PRSVEL (UBAR, UMS, Y, P, VZGAS, VZPAR). This subroutine computes the pressure (P) and axial velocity perturbations (VZGAS and VZPAR) of gas and particles using the supplied mode-amplitude functions and their derivatives (Y). UBAR is the steady-state velocity and UMS is its derivative at the axial location where pressure is to be computed. Pressure is computed from the second order momentum equation (i.e., Equation (24)) and velocity is computed as the axial derivative of the velocity potential. The space-dependent coefficients (CØEF) of Φ_t and Φ_x are computed by subroutine PHICFS and are supplied through the common block BLK3.

SUBRØUTINE RHS (U,UP). This subroutine calculates the right-hand-sides of the equations for the mode-amplitude functions (written as an equivalent first order system); i.e., f_j in the system of equations:

$$dB_j/dt = B_j'$$

$$dB_j'/dt = f_j(B_1, B_2, \ldots, B_1', B_2', \ldots)$$

U is the array containing the mode-amplitude functions and their derivatives

which is supplied to the subroutine, and UP is the array containing the computed values of f_j. The coefficients of the linear and nonlinear terms in the equations for the mode-amplitude functions are supplied from the blank common space. If nonlinear combustion response (using the heuristic model) is to be considered, the necessary additional terms are calculated using the quantities in common block BLK5. Similarly, if nonlinear particle damping is to be considered, common block BLK7 contains the information necessary to calculate the additional terms.

SUBRØUTINE GRØWTH (MAXP, TIMAX, PMAX, FREQ). This subroutine computes the pressure growth rate and frequency of oscillation at the end of each cycle of oscillation. PMAX is an array containing the values of the pressure maxima and minima which are computed in the calling (main) program, TIMAX is an array containing the values of the dimensionless times at which these maxima and minima occur and MAXP gives the total number of maxima and minima. FREQ is the pure-gas acoustic frequency (dimensional) which is needed for converting the nondimensional growth rate and frequency values into dimensional quantities. For computing the growth rate, only pressure maxima are considered, and the exponential growth rate (negative if there is decay) and frequency during each cycle are calculated and stored under the array names ALPHA and F respectively. The subroutine itself prints out these values; the only output of subroutine GRØWTH is this printout.

SUBRØUTINE RESPNS (EN, A, B, ØMEGA, RES). This subroutine calculates the complex combustion response RES according to the two-parameter (A-B) model (Equations (10) and (11)). A and B are the two parameters appearing in Equation (10), EN is the pressure exponent in the steady-state burning law, and ØMEGA is the frequency nondimensionalized by the square of the steady-state burning rate as described in Volume I.

CØMPLEX FUNCTIØN CCØSH (X). This function calculates the hyperbolic cosine (i.e., cosh) of a complex number X.

CØMPLEX FUNCTIØN CSINH(X). This function calculates the hyperbolic sine (i.e., sinh) of a complex number X.

Both CCØSH(X) and CSINH(X) can be omitted in computing facilities where complex arguments are permitted in the hyperbolic functions provided in their library.

SUBRØUTINE GRAPHS (IBUF, NLØC, LDEV, NTØT, NTICX, NTICY, XMAX, YMAX, XMIN, YMIN, ITITLX, ITITLY, LTITLX, LTITLY, XARRAY, YARRAY, DELX, DELY, TITLE). This is the principal plotting subprogram. This subroutine sets up the CALCOMP plotter, calls all other plotting routines and produces the desired plots. First, the different variables to be supplied to this subroutine through the argument list are explained.

IBUF:	address of buffer area for plot output; has dimension NLØC.
NLØC:	number of locations in the buffer area. The most economical value depends on the computation facility being used; on CDC CYBER 70/74 it is 512.
LDEV:	logical device number for plot; 4 in the present program.
NTØT:	number of points to be plotted.
NTICX:	number of tick marks on abscissa.
NTICY:	number of tick marks on ordinate.
XMAX:	upper limit of abscissa domain.
YMAX:	upper limit of ordinate range.
XMIN:	lower limit of abscissa domain.
YMIN:	lower limit of ordinate range.
ITITLX:	abscissa label (alphanumeric).
ITITLY:	ordinate label (alphanumeric).
LTITLX:	number of characters in ITITLX.
LTITLY:	number of characters in ITITLY.
XARRAY:	array containing abscissa values of points to be plotted, in terms of XMIN-XMAX coordinates.
YARRAY:	array containing ordinate values of points to be plotted, in terms of XMIN-XMAX coordinates.
DELX:	interval of abscissa tick mark labelling in terms of XMIN-XMAX coordinates.
DELY:	interval of ordinate tick mark labelling in terms of YMIN-YMAX coordinates.

TITLE: title for the whole run (alphanumeric).

This subroutine first sets up the plotter variables like height of characters (0.105 in), symbol for plotting a point, length of axes on plots, width of margins, etc. It then makes the initial PLØTS call for the CALCOMP plotter. Next, it calls the subroutine MYAXIS to draw the axes and label them. Finally, it calls the subroutine MYLINE to plot the points, draw the optional centerlines, and the page scissorlines. The plotting parameters are supplied to these subroutines through the argument lists and through the common block BLK6.

SUBRØUTINE MYAXIS (NTICX, NTICY, ITITLX, ITITLY, XMAX, YMAX, XMIN, YMIN, LTITLX, LTITLY, DELX, DELY). This subroutine draws the X and Y axes and plots the tick marks on these axes. It calls the subroutine AXLAB to label these axes and the subroutine DENDEC to determine the number of decimal places needed on the tick mark labelling of the axes. The meaning of the argument variables is the same as given above.

SUBRØUTINE MYLINE (XARRAY, YARRAY, XMAX, YMAX, XMIN, YMIN, NTØT, NTICY). This subroutine plots the NTØT points whose abscissae and ordinates are given by XARRAY and YARRAY. If NTICY is negative, it draws the centerline. Finally, it draws the scissorlines for trimming the plots.

SUBRØUTINE AXLAB (ANGLE, IBCD, NCHARX). This subroutine labels the axes. IBCD is the label which is printed and ANGLE is the angle between the line of printing and the direction of movement of the paper on the plotter. NCHARX is the number of characters in the label.

SUBRØUTINE DENDEC (QMAX, DELQ, NDEC). This subroutine determines the number of decimal places NDEC needed on the tick mark labelling of an axis. DELQ is the interval of the axis tick mark labelling and QMAX is the range.

Description of Output. There are two modes of output from this program: (1) printed output, and (2) plotted output. These are described below. The printed output produced by SOLID2 consists of seven sections described below.

Section (1) is a restatement of the input from Program SOLID1. It includes the following information: (a) the mean flow Mach number at the combustor exit (UE), the number of modes considered, the ratio of specific heats (GAMMA) in pure gas and (if particles are present) the ratio of specific heats in the mixture (GAMMABAR); (b) information about the particles (if present); (c) the parameters which describe and identify each term in the series expansion;

(d) the nozzle admittance (YR and YI) and the axial acoustic eigenvalue (EPS and ETA) for each series term; (e) the nonzero linear coefficients if NØUTCF = 1 or 2; and (f) the nonzero nonlinear coefficients if NØUTCF = 2.

Section (2) gives the coefficients needed for computation of the pressure perturbation; i.e., the coefficients in the series for each of the series terms at the two ends and the middle of the chamber.

Section (3) prints out the combustion parameters and the real and imaginary parts of the response functions. If a nonlinear combustion response is considered, the parameter b in the heuristic nonlinear combustion model is given.

Section (4) gives the acoustic frequency and initial amplitudes of all the series terms included in the assumed initial disturbance.

Section (5) is printed only if NHISTR = 0. In this section, the time histories of (a) the pressure disturbance at the two ends and the middle of the chamber and (b) the gas and particle velocity perturbations at the middle of the chamber are printed out, starting at time t = TSTART and ending at time t = TQUIT (TSTART and TQUIT having been specified in the input).

Section (6) gives the pressure maxima and minima values at the chamber location specified by NLØC. This information is printed as an array of number pairs giving the value of the pressure maximum or minimum (upper numbers) and the corresponding time of maximum or minimum (lower number).

In section (7), average pressure growth rate and frequency of oscillation in each cycle are printed out. This information is printed as an array of number triads giving the value of the pressure growth rate (upper number), frequency of oscillation (middle number) and the dimensionless time at the mid-point of the cycle (lower number).

According to the value of NØUT the pressure waveforms at the ends and middle of the chamber may be plotted. Furthermore, waveforms of individual mode amplitudes may also be plotted depending on the specified values of elements in the array MDPLØT (see the description of inputs for details). All the plots have dimensionless time as the abscissa. The range of the abscissa for each plot is 10 units, and the first plot starts with t = TSTART. Thus for each quantity whose plot is desired, N plots are produced where N is the largest multiple of 10 contained in the interval TSTART to TQUIT. All quantities to be plotted for a given time interval are plotted before proceeding to the next time interval. All of the plots are scaled to fit on standard (8½ in x 11 in) paper and scissor-lines are plotted for trimming plots to this size. The data

is plotted as individual points using a centered circle symbol. Before the first plot is produced the identifying title is printed.

Sample Case. A sample case is now presented to facilitate checkout. Pressure-time histories are obtained for the motor considered in the sample case for SOLID1. The data generated by SOLID1 is used for the second part of the necessary input for SOLID2 through a data file stored on disk. Since the purpose of this run is only to illustrate the operation of SOLID2, TQUIT = 10.0 and only linear combustion response (NCØMB = 0) and linear particle damping (NNPRT = 0) are considered. The combustion parameters are A = 5.996, B = 0.58, n = 0.575, and Ω = 4.20. A step size of 0.025 is chosen. A 1L-mode initial disturbance of 10% pressure amplitude is considered, for which the formula given previously yields ACT = 0.0 and AST = - 0.0266818.

Pressure maxima and minima are obtained at the head end; hence NLØC = 1. To check out the plotting routine, plots of the pressure disturbance are obtained at the two ends of the chamber as well as at the middle, hence NØUT = 3. Plots of the first five longitudinal modes are obtained by punching 1 at the 5th, 10th, 15th, 20th, and 25th columns of the appropriate card in the input deck.

An input deck with the above data is illustrated on the next page. The printed output and the plotted output generated by Program SOLID2, using this deck and the coefficients generated by Program SOLID1, are presented in the following pages.

```
    0    0
TEST CASE FØR SØLID2
     0.025       0.0      10.0    1071.0       0.0
     5.996      0.58     0.575       4.2
    1    1    3    0    0
      0.15      0.05  -31
    1    1    1    1    1
      0.04      0.01  -41
    1 -.0266818       0.0
```

UE = .0780

NUMBER OF MODES = 5

GAMMA = 1.23

GAMMABAR = 1.212250

PARTICLE DIA (IN MICRONS) = 2.5   CM = .10   FREQ (IN HERTZ) = 1071.0

CHAMBER TEMP (IN DEG K) = 3525.0   SP = .68   RHOM (IN KG/CUBIC METER) = 4000.0

PARTICLE DRAG CONSTANT, K = 29.9186

NAME	J	L
1L	1	1
2L	2	2
3L	3	3
4L	4	4
5L	5	5

J	YR	YI	EPS	ETA
1	.00683	0.00000	3.14159	.00828
2	.00683	0.00000	6.28319	.00828
3	.00683	0.00000	9.42478	.00828
4	.00683	0.00000	12.56637	.00828
5	.00683	0.00000	15.70796	.00828

COEFFICIENTS FOR COMPUTATION OF WALL PRESSURE WAVEFORMS

COEFFICIENTS IN SERIES FOR:

J	Z	TIME DERIVATIVE	AXIAL DERIVATIVE
1	0.000	1.0000000	0.0000000
2	0.000	0.0000000	0.0000000
3	0.000	1.0000000	0.0000000
4	0.000	0.0000000	0.0000000
5	0.000	1.0000000	0.0000000
6	0.000	0.0000000	0.0000000
7	0.000	1.0000000	0.0000000
8	0.000	0.0000000	0.0000000
9	0.000	1.0000000	0.0000000
10	0.000	0.0000000	0.0000000
1	1.000	-1.0000343	-.0000685
2	1.000	.0000000	-.0260059
3	1.000	1.0000343	.0000685
4	1.000	.0000000	.0520119
5	1.000	-1.0000343	-.0000685
6	1.000	.0000000	-.0780178
7	1.000	1.0000343	.0000686
8	1.000	-.0000000	.1040237
9	1.000	-1.0000343	-.0000685
10	1.000	-.0000000	-.1300296
1	.500	.0000000	-3.1416196
2	.500	.0041389	.0082779
3	.500	-1.0000086	-.0000343
4	.500	-.0000000	-.0260057
5	.500	-.0000000	9.4246587
6	.500	-.0041389	-.0082779
7	.500	1.0000086	.0000343
8	.500	-.0000000	.0520114
9	.500	-.0000000	-15.7080978
10	.500	.0041389	.0082779

COMBUSTION PARAMETERS: A = 5.996   B = .580   EN = .575   OMEGA = 4.200

J	RESR	RESI
1	4.1401	.0926
2	.9605	-1.7016
3	.5013	-1.0872
4	.3777	-.8191
5	.3134	-.6694

LINEAR COMBUSTION RESPONSE.

LINEAR PARTICLE DAMPING.

```
INITIAL CONDITIONS ARE OF THE FORM:

U(I,J) =   AC(J)*COS(FREQ*T) + AS(J)*SIN(FREQ*T)

  J      FREQUENCY          AC(J)          AS(J)

  1      2.97369626     0.00000000     -.02668180
  2      2.97369626      .02523957      .00007032

THIS RUN PRODUCES PLOTTED OUTPUT.
```

MOTOR PARAMETERS: GAMMA = 1.23 EXIT MACH NUMBER = .07800

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
0	0.00000	.10000	-.09231	-.00002	.00021	.00021
1	.02500	.09959	-.09328	-.00008	.00626	.00203
2	.05000	.09874	-.09349	-.00014	.01206	.00598
3	.07500	.09735	-.09309	-.00020	.01771	.01084
4	.10000	.09540	-.09210	-.00027	.02322	.01606
5	.12500	.09287	-.09055	-.00035	.02857	.02136
6	.15000	.08980	-.08845	-.00045	.03376	.02665
7	.17500	.08621	-.08579	-.00057	.03875	.03181
8	.20000	.08214	-.08243	-.00073	.04352	.03660
9	.22500	.07762	-.07834	-.00093	.04804	.04159
10	.25000	.07269	-.07457	-.00118	.05229	.04615
11	.27500	.06740	-.06981	-.00149	.05624	.05044
12	.30000	.06178	-.06455	-.00186	.05988	.05445
13	.32500	.05590	-.05885	-.00229	.06319	.05816
14	.35000	.04977	-.05271	-.00278	.06615	.06154
15	.37500	.04346	-.04618	-.00334	.06877	.06460
16	.40000	.03698	-.03923	-.00396	.07101	.06730
17	.42500	.03039	-.03207	-.00463	.07289	.06964
18	.45000	.02372	-.02457	-.00535	.07437	.07162
19	.47500	.01700	-.01683	-.00610	.07547	.07322
20	.50000	.01026	-.00891	-.00686	.07617	.07443
21	.52500	.00354	-.00085	-.00763	.07646	.07525
22	.55000	-.00314	.00729	-.00838	.07635	.07567
23	.57500	-.00975	.01545	-.00909	.07581	.07568
24	.60000	-.01626	.02356	-.00975	.07486	.07528
25	.62500	-.02263	.03155	-.01033	.07349	.07447
26	.65000	-.02885	.03937	-.01082	.07171	.07325
27	.67500	-.03489	.04695	-.01120	.06952	.07161
28	.70000	-.04073	.05422	-.01146	.06692	.06957
29	.72500	-.04635	.06113	-.01158	.06393	.06713
30	.75000	-.05173	.06763	-.01154	.06056	.06429
31	.77500	-.05686	.07365	-.01136	.05684	.06108
32	.80000	-.06173	.07916	-.01101	.05277	.05751
33	.82500	-.06633	.08414	-.01050	.04837	.05359
34	.85000	-.07066	.08853	-.00983	.04358	.04934
35	.87500	-.07470	.09233	-.00901	.03871	.04479
36	.90000	-.07845	.09552	-.00804	.03349	.03996
37	.92500	-.08190	.09809	-.00695	.02805	.03487
38	.95000	-.08503	.10003	-.00574	.02243	.02956
39	.97500	-.08785	.10135	-.00444	.01665	.02405
40	1.00000	-.09032	.10204	-.00307	.01075	.01838
41	1.02500	-.09242	.10213	-.00166	.00476	.01258
42	1.05000	-.09415	.10162	-.00022	-.00127	.00668
43	1.07500	-.09546	.10053	.00121	-.00730	.00072

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
44	1.10000	-.09633	.09888	.00260	-.01330	-.00525
45	1.12500	-.09673	.09669	.00394	-.01922	-.01120
46	1.15000	-.09663	.09400	.00519	-.02502	-.01708
47	1.17500	-.09600	.09082	.00632	-.03065	-.02286
48	1.20000	-.09480	.08720	.00732	-.03609	-.02850
49	1.22500	-.09302	.08316	.00816	-.04129	-.03395
50	1.25000	-.09062	.07873	.00883	-.04622	-.03918
51	1.27500	-.08759	.07396	.00931	-.05086	-.04416
52	1.30000	-.08391	.06893	.00959	-.05513	-.04885
53	1.32500	-.07957	.06352	.00967	-.05916	-.05324
54	1.35000	-.07457	.05791	.00955	-.06279	-.05731
55	1.37500	-.06891	.05209	.00922	-.06605	-.06103
56	1.40000	-.06261	.04608	.00871	-.06894	-.06439
57	1.42500	-.05570	.03993	.00801	-.07145	-.06739
58	1.45000	-.04822	.03366	.00716	-.07357	-.07001
59	1.47500	-.04020	.02729	.00615	-.07532	-.07226
60	1.50000	-.03171	.02085	.00502	-.07668	-.07413
61	1.52500	-.02283	.01437	.00379	-.07766	-.07561
62	1.55000	-.01363	.00788	.00248	-.07825	-.07671
63	1.57500	-.00420	.00140	.00112	-.07845	-.07743
64	1.60000	.00535	-.00504	-.00027	-.07827	-.07776
65	1.62500	.01493	-.01143	-.00166	-.07770	-.07771
66	1.65000	.02442	-.01774	-.00302	-.07674	-.07727
67	1.67500	.03374	-.02394	-.00432	-.07539	-.07644
68	1.70000	.04276	-.03002	-.00553	-.07365	-.07523
69	1.72500	.05142	-.03596	-.00663	-.07152	-.07362
70	1.75000	.05961	-.04174	-.00760	-.06900	-.07162
71	1.77500	.06726	-.04735	-.00840	-.06608	-.06924
72	1.80000	.07433	-.05277	-.00901	-.06278	-.06646
73	1.82500	.08075	-.05799	-.00942	-.05909	-.06330
74	1.85000	.08649	-.06300	-.00961	-.05502	-.05975
75	1.87500	.09154	-.06779	-.00956	-.05058	-.05582
76	1.90000	.09587	-.07234	-.00927	-.04579	-.05151
77	1.92500	.09949	-.07665	-.00874	-.04063	-.04685
78	1.95000	.10240	-.08069	-.00797	-.03517	-.04185
79	1.97500	.10461	-.08446	-.00699	-.02942	-.03653
80	2.00000	.10613	-.08794	-.00582	-.02342	-.03091
81	2.02500	.10699	-.09111	-.00449	-.01720	-.02504
82	2.05000	.10721	-.09393	-.00303	-.01082	-.01895
83	2.07500	.10680	-.09640	-.00149	-.00433	-.01268
84	2.10000	.10579	-.09848	.00008	.00221	-.00629
85	2.12500	.10421	-.10015	.00162	.00874	.00016
86	2.15000	.10208	-.10136	.00309	.01521	.00662
87	2.17500	.09943	-.10208	.00444	.02154	.01303
88	2.20000	.09629	-.10227	.00562	.02769	.01933
89	2.22500	.09270	-.10188	.00658	.03360	.02546
90	2.25000	.08868	-.10087	.00729	.03923	.03137
91	2.27500	.08428	-.09918	.00774	.04454	.03703

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
92	2.30000	.07953	-.09677	.00790	.04953	.04238
93	2.32500	.07447	-.09353	.00777	.05410	.04740
94	2.35000	.06913	-.08958	.00737	.05833	.05207
95	2.37500	.06355	-.08473	.00669	.06216	.05636
96	2.40000	.05776	-.07902	.00577	.06561	.06031
97	2.42500	.05179	-.07243	.00464	.06867	.06386
98	2.45000	.04567	-.06498	.00332	.07135	.06702
99	2.47500	.03942	-.05673	.00185	.07366	.06981
100	2.50000	.03309	-.04773	.00026	.07559	.07223
101	2.52500	.02669	-.03807	-.00142	.07715	.07427
102	2.55000	.02026	-.02788	-.00314	.07834	.07594
103	2.57500	.01381	-.01730	-.00490	.07917	.07725
104	2.60000	.00739	-.00647	-.00667	.07964	.07819
105	2.62500	.00101	.00445	-.00842	.07975	.07878
106	2.65000	-.00530	.01528	-.01013	.07950	.07900
107	2.67500	-.01151	.02588	-.01179	.07890	.07867
108	2.70000	-.01761	.03610	-.01337	.07795	.07839
109	2.72500	-.02358	.04580	-.01485	.07666	.07757
110	2.75000	-.02942	.05489	-.01619	.07501	.07639
111	2.77500	-.03510	.06329	-.01738	.07301	.07486
112	2.80000	-.04063	.07095	-.01837	.07065	.07299
113	2.82500	-.04601	.07783	-.01914	.06792	.07075
114	2.85000	-.05123	.08394	-.01964	.06480	.06815
115	2.87500	-.05629	.08927	-.01983	.06128	.06517
116	2.90000	-.06118	.09386	-.01970	.05734	.06180
117	2.92500	-.06589	.09774	-.01920	.05297	.05802
118	2.95000	-.07042	.10092	-.01833	.04817	.05381
119	2.97500	-.07473	.10347	-.01708	.04293	.04919
120	3.00000	-.07880	.10539	-.01546	.03727	.04413
121	3.02500	-.08262	.10671	-.01347	.03121	.03866
122	3.05000	-.08617	.10746	-.01117	.02480	.03280
123	3.07500	-.08941	.10765	-.00859	.01810	.02658
124	3.10000	-.09234	.10730	-.00580	.01117	.02006
125	3.12500	-.09493	.10640	-.00287	.00409	.01330
126	3.15000	-.09718	.10499	.00012	-.00304	.00637
127	3.17500	-.09908	.10307	.00309	-.01015	-.00064
128	3.20000	-.10062	.10065	.00594	-.01713	-.00765
129	3.22500	-.10179	.09778	.00860	-.02390	-.01457
130	3.25000	-.10257	.09446	.01098	-.03040	-.02132
131	3.27500	-.10293	.09074	.01303	-.03656	-.02783
132	3.30000	-.10282	.08666	.01470	-.04233	-.03403
133	3.32500	-.10219	.08224	.01594	-.04768	-.03986
134	3.35000	-.10095	.07752	.01674	-.05260	-.04533
135	3.37500	-.09903	.07254	.01711	-.05709	-.05037
136	3.40000	-.09632	.06731	.01706	-.06115	-.05499
137	3.42500	-.09272	.06187	.01661	-.06480	-.05919
138	3.45000	-.08815	.05622	.01583	-.06805	-.06297
139	3.47500	-.08251	.05040	.01474	-.07093	-.06637

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
140	3.50000	-.07577	.04441	.01341	-.07344	[illegible]
141	3.52500	-.06790	.03827	.01188	-.07559	[illegible]
142	3.55000	-.05893	.03201	.01021	-.07743	[illegible]
143	3.57500	-.04893	.02564	.00844	-.07887	[illegible]
144	3.60000	-.03801	.01919	.00660	-.07998	[illegible]
145	3.62500	-.02635	.01271	.00471	-.08075	[illegible]
146	3.65000	-.01414	.00622	.00280	-.08116	[illegible]
147	3.67500	-.00162	-.00025	.00087	-.08122	[illegible]
148	3.70000	.01098	-.00664	-.00107	-.08094	[illegible]
149	3.72500	.02340	-.01294	-.00301	-.08032	[illegible]
150	3.75000	.03541	-.01912	-.00495	-.07936	[illegible]
151	3.77500	.04680	-.02516	-.00687	-.07809	[illegible]
152	3.80000	.05740	-.03106	-.00875	-.07649	[illegible]
153	3.82500	.06708	-.03682	-.01055	-.07456	[illegible]
154	3.85000	.07575	-.04244	-.01224	-.07235	[illegible]
155	3.87500	.08339	-.04792	-.01376	-.06978	[illegible]
156	3.90000	.08999	-.05329	-.01505	-.06684	[illegible]
157	3.92500	.09559	-.05853	-.01605	-.06349	[illegible]
158	3.95000	.10027	-.06365	-.01669	-.05970	[illegible]
159	3.97500	.10409	-.06862	-.01691	-.05543	[illegible]
160	4.00000	.10714	-.07344	-.01668	-.05064	-.05823
161	4.02500	.10950	-.07805	-.01595	-.04531	-.05159
162	4.05000	.11123	-.08244	-.01472	-.03943	-.04643
163	4.07500	.11238	-.08656	-.01300	-.03303	-.04074
164	4.10000	.11298	-.09038	-.01084	-.02614	-.03493
165	4.12500	.11304	-.09386	-.00828	-.01885	-.02784
166	4.15000	.11257	-.09699	-.00543	-.01124	-.02075
167	4.17500	.11156	-.09976	-.00239	-.00344	-.01334
168	4.20000	.10999	-.10217	.00071	.00441	-.00572
169	4.22500	.10783	-.10423	.00376	.01220	.00200
170	4.25000	.10522	-.10594	.00660	.01977	.00967
171	4.27500	.10204	-.10730	.00913	.02702	.01718
172	4.30000	.09837	-.10829	.01125	.03384	.02440
173	4.32500	.09425	-.10887	.01286	.04017	.03124
174	4.35000	.08973	-.10897	.01391	.04596	.03782
175	4.37500	.08488	-.10843	.01439	.05120	.04351
176	4.40000	.07974	-.10723	.01430	.05590	.04886
177	4.42500	.07436	-.10523	.01368	.06011	.05370
178	4.45000	.06879	-.10214	.01259	.06386	.05805
179	4.47500	.06303	-.09787	.01111	.06720	.06194
180	4.50000	.05711	-.09226	.00933	.07019	.06543
181	4.52500	.05104	-.08523	.00734	.07286	.06854
182	4.55000	.04480	-.07674	.00522	.07522	.07132
183	4.57500	.03841	-.06680	.00306	.07729	.07379
184	4.60000	.03187	-.05553	.00090	.07905	.07595
185	4.62500	.02521	-.04312	-.00121	.08048	.07780
186	4.65000	.01847	-.02980	-.00325	.08157	.07933
187	4.67500	.01170	-.01590	-.00524	.08228	.08052

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
188	4.70000	.00495	-.00177	-.00717	.08262	.08134
189	4.72500	-.00170	.01224	-.00906	.08257	.08179
190	4.75000	-.00920	.02578	-.01095	.08215	.08186
191	4.77500	-.01450	.03655	-.01283	.08139	.08157
192	4.80000	-.02056	.05032	-.01473	.08032	.08093
193	4.82500	-.02638	.06090	-.01663	.07698	.07998
194	4.85000	-.03195	.07022	-.01851	.07739	.07875
195	4.87500	-.03732	.07826	-.02031	.07557	.07726
196	4.90000	-.04252	.08507	-.02199	.07352	.07553
197	4.92500	-.04760	.09077	-.02345	.07120	.07356
198	4.95000	-.05260	.09549	-.02462	.06856	.07132
199	4.97500	-.05758	.09937	-.02542	.06552	.06677
200	5.00000	-.06252	.10258	-.02576	.06201	.06584
201	5.02500	-.06744	.10524	-.02555	.05794	.06245
202	5.05000	-.07228	.10743	-.02477	.05322	.05854
203	5.07500	-.07699	.10922	-.02336	.04781	.05403
204	5.10000	-.08149	.11062	-.02131	.04169	.04886
205	5.12500	-.08570	.11163	-.01865	.03488	.04302
206	5.15000	-.08955	.11220	-.01543	.02745	.03650
207	5.17500	-.09297	.11229	-.01174	.01950	.02938
208	5.20000	-.09593	.11184	-.00767	.01117	.02173
209	5.22500	-.09844	.11031	-.00338	.00263	.01368
210	5.25000	-.10050	.10917	.00099	-.00592	.00539
211	5.27500	-.10219	.10693	.00530	-.01430	-.00297
212	5.30000	-.10357	.10411	.00936	-.02236	-.01123
213	5.32500	-.10472	.10075	.01305	-.02993	-.01924
214	5.35000	-.10568	.09692	.01623	-.03693	-.02683
215	5.37500	-.10650	.09270	.01881	-.04328	-.03392
216	5.40000	-.10715	.08816	.02071	-.04897	-.04042
217	5.42500	-.10755	.08337	.02190	-.05402	-.04629
218	5.45000	-.10759	.07838	.02240	-.05646	-.05156
219	5.47500	-.10706	.07322	.02223	-.06241	-.05624
220	5.50000	-.10574	.06791	.02148	-.06591	-.06039
221	5.52500	-.10338	.06243	.02024	-.06904	-.06409
222	5.55000	-.09971	.05676	.01861	-.07188	-.06740
223	5.57500	-.09452	.05088	.01672	-.07446	-.07039
224	5.60000	-.08764	.04476	.01466	-.07681	-.07309
225	5.62500	-.07896	.03839	.01253	-.07891	-.07553
226	5.65000	-.06850	.03179	.01041	-.08073	-.07771
227	5.67500	-.05836	.02498	.00834	-.08224	-.07961
228	5.70000	-.04277	.01802	.00636	-.08339	-.08119
229	5.72500	-.02804	.01100	.00445	-.08413	-.08242
230	5.75000	-.01258	.00399	.00260	-.08445	-.08327
231	5.77500	.00321	-.00291	.00077	-.08434	-.08371
232	5.80000	.01683	-.00961	-.00109	-.08382	-.08374
233	5.82500	.03385	-.01607	-.00302	-.08293	-.08336
234	5.85000	.04790	-.02225	-.00505	-.08173	-.08263
235	5.87500	.06066	-.02814	-.00721	-.08027	-.08157

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	FAR VEL AT Z=0.5
236	5.90000	.07193	-.03378	-.00948	-.07861	-.08024
237	5.92500	.08161	-.03921	-.01183	-.07677	-.07870
238	5.95000	.08969	-.04451	-.01419	-.07478	-.07695
239	5.97500	.09628	-.04974	-.01647	-.07258	-.07503
240	6.00000	.10153	-.05497	-.01855	-.07013	-.07289
241	6.02500	.10563	-.06022	-.02031	-.06732	-.07049
242	6.05000	.10882	-.06552	-.02161	-.06404	-.06774
243	6.07500	.11129	-.07082	-.02233	-.06015	-.06453
244	6.10000	.11324	-.07607	-.02236	-.05554	-.06075
245	6.12500	.11479	-.08118	-.02164	-.05012	-.05630
246	6.15000	.11601	-.08604	-.02012	-.04383	-.05107
247	6.17500	.11694	-.09055	-.01781	-.03667	-.04502
248	6.20000	.11752	-.09462	-.01478	-.02873	-.03816
249	6.22500	.11770	-.09818	-.01113	-.02012	-.03052
250	6.25000	.11739	-.10121	-.00701	-.01103	-.02223
251	6.27500	.11648	-.10374	-.00260	-.00168	-.01344
252	6.30000	.11492	-.10583	.00187	.00767	-.00436
253	6.32500	.11265	-.10757	.00619	.01679	.00478
254	6.35000	.10968	-.10906	.01015	.02543	.01376
255	6.37500	.10603	-.11041	.01354	.03342	.02234
256	6.40000	.10178	-.11166	.01623	.04062	.03035
257	6.42500	.09705	-.11283	.01809	.04698	.03764
258	6.45000	.09194	-.11384	.01906	.05248	.04416
259	6.47500	.08658	-.11455	.01916	.05720	.04987
260	6.50000	.08105	-.11471	.01844	.06124	.05482
261	6.52500	.07543	-.11404	.01701	.06474	.05909
262	6.55000	.06974	-.11218	.01501	.06783	.06281
263	6.57500	.06398	-.10881	.01260	.07066	.06610
264	6.60000	.05806	-.10360	.00996	.07331	.06907
265	6.62500	.05198	-.09633	.00723	.07584	.07183
266	6.65000	.04564	-.08688	.00455	.07825	.07444
267	6.67500	.03901	-.07525	.00202	.08050	.07689
268	6.70000	.03207	-.06161	-.00030	.08251	.07917
269	6.72500	.02484	-.04630	-.00239	.08418	.08122
270	6.75000	.01739	-.02975	-.00428	.08543	.08295
271	6.77500	.00985	-.01253	-.00601	.08618	.08429
272	6.80000	.00234	.00477	-.00765	.08639	.08515
273	6.82500	-.00499	.02156	-.00928	.08607	.08551
274	6.85000	-.01200	.03729	-.01099	.08526	.08536
275	6.87500	-.01858	.05153	-.01283	.08405	.08473
276	6.90000	-.02469	.06398	-.01483	.08255	.08370
277	6.92500	-.03031	.07450	-.01699	.08089	.08235
278	6.95000	-.03550	.08309	-.01927	.07912	.08080
279	6.97500	-.04035	.08990	-.02161	.07734	.07913
280	7.00000	-.04501	.09517	-.02390	.07554	.07739
281	7.02500	-.04962	.09921	-.02602	.07367	.07560
282	7.05000	-.05432	.10233	-.02783	.07162	.07373
283	7.07500	-.05920	.10485	-.02920	.06922	.07167

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
284	7.10000	-.06430	.10703	-.03000	.06629	.06931
285	7.12500	-.06961	.10904	-.03011	.06263	.06646
286	7.15000	-.07504	.11098	-.02944	.05603	.06295
287	7.17500	-.08045	.11287	-.02792	.05250	.05862
288	7.20000	-.08565	.11463	-.02555	.04586	.05336
289	7.22500	-.09047	.11613	-.02234	.03816	.04706
290	7.25000	-.09473	.11723	-.01838	.02952	.03981
291	7.27500	-.09831	.11775	-.01377	.02013	.03163
292	7.30000	-.10114	.11755	-.00869	.01026	.02269
293	7.32500	-.10323	.11655	-.00331	.00018	.01322
294	7.35000	-.10469	.11470	.00214	-.00979	.00348
295	7.37500	-.10565	.11202	.00745	-.01935	-.00624
296	7.40000	-.10632	.10859	.01240	-.02626	-.01566
297	7.42500	-.10690	.10454	.01679	-.03634	-.02458
298	7.45000	-.10757	.10001	.02046	-.04346	-.03276
299	7.47500	-.10844	.09515	.02326	-.04961	-.04009
300	7.50000	-.10955	.09011	.02514	-.05483	-.04652
301	7.52500	-.11082	.08499	.02608	-.05923	-.05207
302	7.55000	-.11204	.07984	.02610	-.06297	-.05661
303	7.57500	-.11290	.07467	.02531	-.06623	-.06088
304	7.60000	-.11301	.06945	.02384	-.06917	-.06443
305	7.62500	-.11193	.06409	.02183	-.07193	-.06761
306	7.65000	-.10921	.05850	.01947	-.07462	-.07054
307	7.67500	-.10446	.05257	.01691	-.07725	-.07333
308	7.70000	-.09739	.04623	.01433	-.07983	-.07602
309	7.72500	-.08784	.03944	.01183	-.08227	-.07860
310	7.75000	-.07581	.03220	.00950	-.08447	-.08104
311	7.77500	-.06148	.02460	.00740	-.08630	-.08324
312	7.80000	-.04523	.01676	.00553	-.08766	-.08511
313	7.82500	-.02759	.00884	.00385	-.08844	-.08653
314	7.85000	-.00906	.00102	.00229	-.08861	-.08744
315	7.87500	.00957	-.00653	.00077	-.08813	-.08777
316	7.90000	.02765	-.01365	-.00082	-.08720	-.08753
317	7.92500	.04460	-.02027	-.00257	-.08578	-.08677
318	7.95000	.05990	-.02634	-.00456	-.08405	-.08557
319	7.97500	.07322	-.03191	-.00682	-.08216	-.08405
320	8.00000	.08438	-.03707	-.00937	-.08023	-.08232
321	8.02500	.09336	-.04196	-.01215	-.07834	-.08051
322	8.05000	.10032	-.04676	-.01506	-.07652	-.07866
323	8.07500	.10551	-.05161	-.01799	-.07470	-.07687
324	8.10000	.10927	-.05667	-.02075	-.07278	-.07504
325	8.12500	.11197	-.06200	-.02317	-.07058	-.07309
326	8.15000	.11398	-.06762	-.02504	-.06786	-.07086
327	8.17500	.11560	-.07347	-.02620	-.06440	-.06816
328	8.20000	.11706	-.07942	-.02648	-.05997	-.06477
329	8.22500	.11849	-.08528	-.02577	-.05441	-.06050
330	8.25000	.11990	-.09083	-.02402	-.04763	-.05519
331	8.27500	.12124	-.09587	-.02123	-.03963	-.04873

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
332	8.30000	.12235	-.10023	-.01749	-.03052	-.04112
333	8.32500	.12304	-.10381	-.01294	-.02052	-.03244
334	8.35000	.12312	-.10657	-.00780	-.00991	-.02288
335	8.37500	.12241	-.10859	-.00233	.00095	-.01268
336	8.40000	.12079	-.11001	.00318	.01169	-.00218
337	8.42500	.11821	-.11105	.00844	.02194	.00830
338	8.45000	.11469	-.11193	.01317	.03138	.01839
339	8.47500	.11034	-.11283	.01710	.03979	.02761
340	8.50000	.10533	-.11406	.02006	.04702	.03631
341	8.52500	.09984	-.11553	.02192	.05307	.04375
342	8.55000	.09408	-.11723	.02263	.05800	.05008
343	8.57500	.08824	-.11894	.02224	.06198	.05534
344	8.60000	.08243	-.12033	.02085	.06524	.05967
345	8.62500	.07674	-.12092	.01865	.06803	.06325
346	8.65000	.07113	-.12019	.01586	.07060	.06632
347	8.67500	.06553	-.11762	.01270	.07312	.06908
348	8.70000	.05981	-.11271	.00940	.07573	.07174
349	8.72500	.05380	-.10510	.00618	.07846	.07440
350	8.75000	.04736	-.09463	.00318	.08126	.07712
351	8.77500	.04039	-.08131	.00052	.08400	.07988
352	8.80000	.03285	-.06540	-.00177	.08651	.08258
353	8.82500	.02481	-.04738	-.00370	.08859	.08506
354	8.85000	.01639	-.02793	-.00532	.09008	.08717
355	8.87500	.00781	-.00784	-.00674	.09084	.08875
356	8.90000	-.00069	.01205	-.00805	.09083	.08967
357	8.92500	-.00885	.03093	-.00948	.09007	.08986
358	8.95000	-.01645	.04811	-.01104	.08867	.08936
359	8.97500	-.02333	.06308	-.01285	.08682	.08823
360	9.00000	-.02940	.07554	-.01495	.08471	.08662
361	9.02500	-.03469	.08545	-.01733	.08256	.08472
362	9.05000	-.03933	.09295	-.01994	.08054	.08270
363	9.07500	-.04351	.09836	-.02267	.07874	.08074
364	9.10000	-.04749	.10213	-.02539	.07719	.07893
365	9.12500	-.05154	.10475	-.02795	.07576	.07730
366	9.15000	-.05589	.10671	-.03018	.07429	.07578
367	9.17500	-.06071	.10841	-.03191	.07251	.07422
368	9.20000	-.06606	.11017	-.03298	.07012	.07239
369	9.22500	-.07191	.11217	-.03325	.06681	.07003
370	9.25000	-.07810	.11444	-.03260	.06232	.06686
371	9.27500	-.08437	.11691	-.03096	.05647	.06263
372	9.30000	-.09042	.11937	-.02831	.04917	.05716
373	9.32500	-.09595	.12157	-.02468	.04049	.05035
374	9.35000	-.10068	.12324	-.02017	.03060	.04223
375	9.37500	-.10442	.12410	-.01491	.01980	.03294
376	9.40000	-.10707	.12397	-.00910	.00846	.02272
377	9.42500	-.10869	.12274	-.00297	-.00300	.01189
378	9.45000	-.10943	.12039	.00323	-.01415	.00084
379	9.47500	-.10955	.11702	.00923	-.02460	-.01005

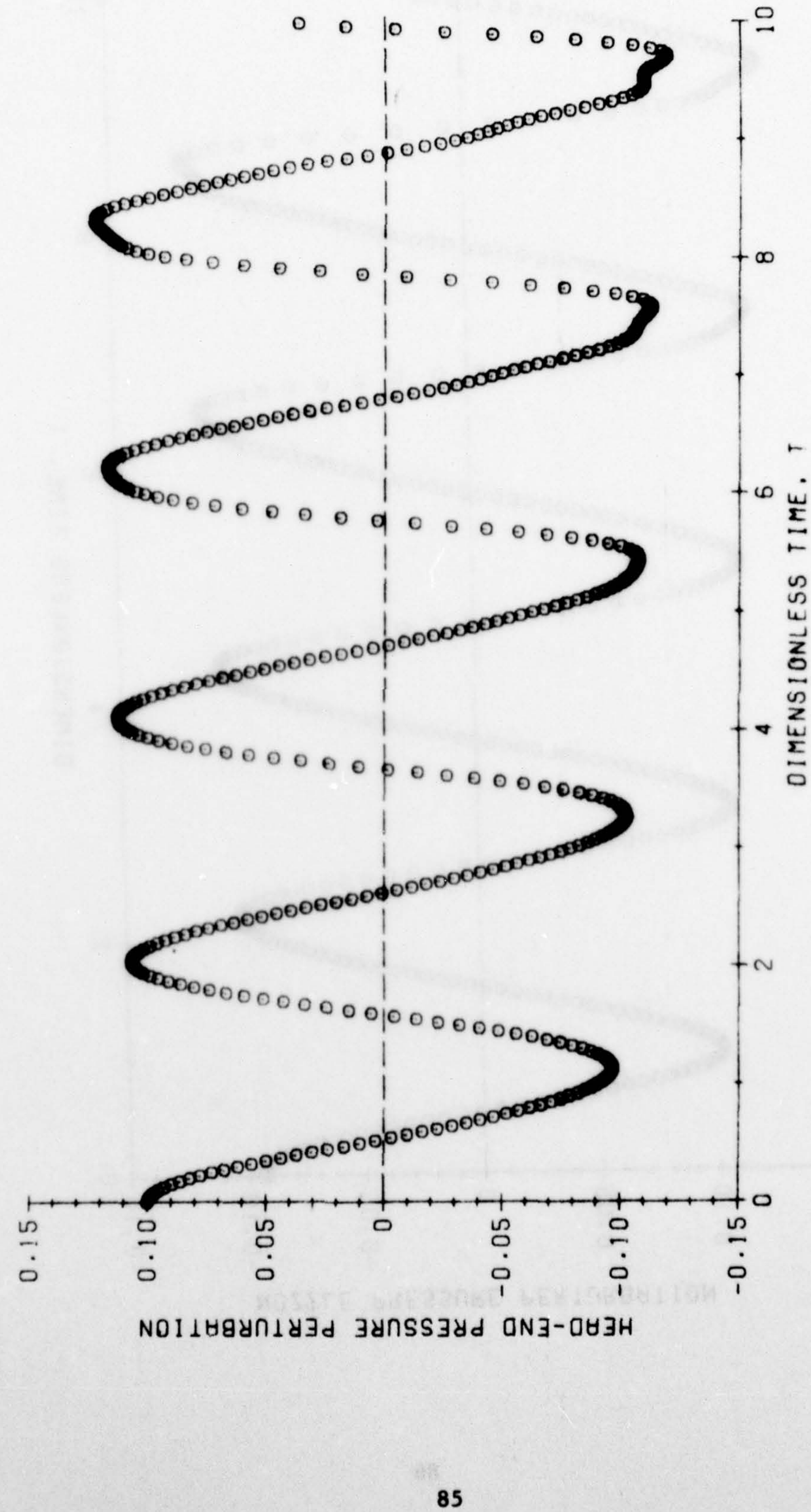
STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
380	9.50000	-.10939	.11260	.01477	-.03406	-.02040
381	9.52500	-.10927	.10794	.01962	-.04232	-.02992
382	9.55000	-.10951	.10269	.02358	-.04928	-.03838
383	9.57500	-.11031	.09727	.02650	-.05500	-.04568
384	9.60000	-.11173	.09186	.02831	-.05960	-.05161
385	9.62500	-.11368	.08659	.02901	-.06331	-.05687
386	9.65000	-.11587	.08149	.02865	-.06638	-.06102
387	9.67500	-.11787	.07650	.02736	-.06909	-.06450
388	9.70000	-.11912	.07151	.02532	-.07167	-.06753
389	9.72500	-.11900	.06636	.02274	-.07431	-.07034
390	9.75000	-.11690	.06084	.01984	-.07711	-.07311
391	9.77500	-.11230	.05480	.01681	-.08006	-.07594
392	9.80000	-.10480	.04809	.01385	-.08309	-.07886
393	9.82500	-.09423	.04068	.01109	-.08604	-.08182
394	9.85000	-.08061	.03260	.00863	-.08872	-.08469
395	9.87500	-.06423	.02400	.00651	-.09092	-.08732
396	9.90000	-.04559	.01509	.00472	-.09246	-.08953
397	9.92500	-.02538	.00614	.00321	-.09321	-.09114
398	9.95000	-.00443	-.00255	.00186	-.09312	-.09205
399	9.97500	.01639	-.01073	.00056	-.09224	-.09219
400	10.00000	.03626	-.01820	-.00084	-.09068	-.09158
401	10.02500	.05444	-.02485	-.00247	-.08862	-.09032

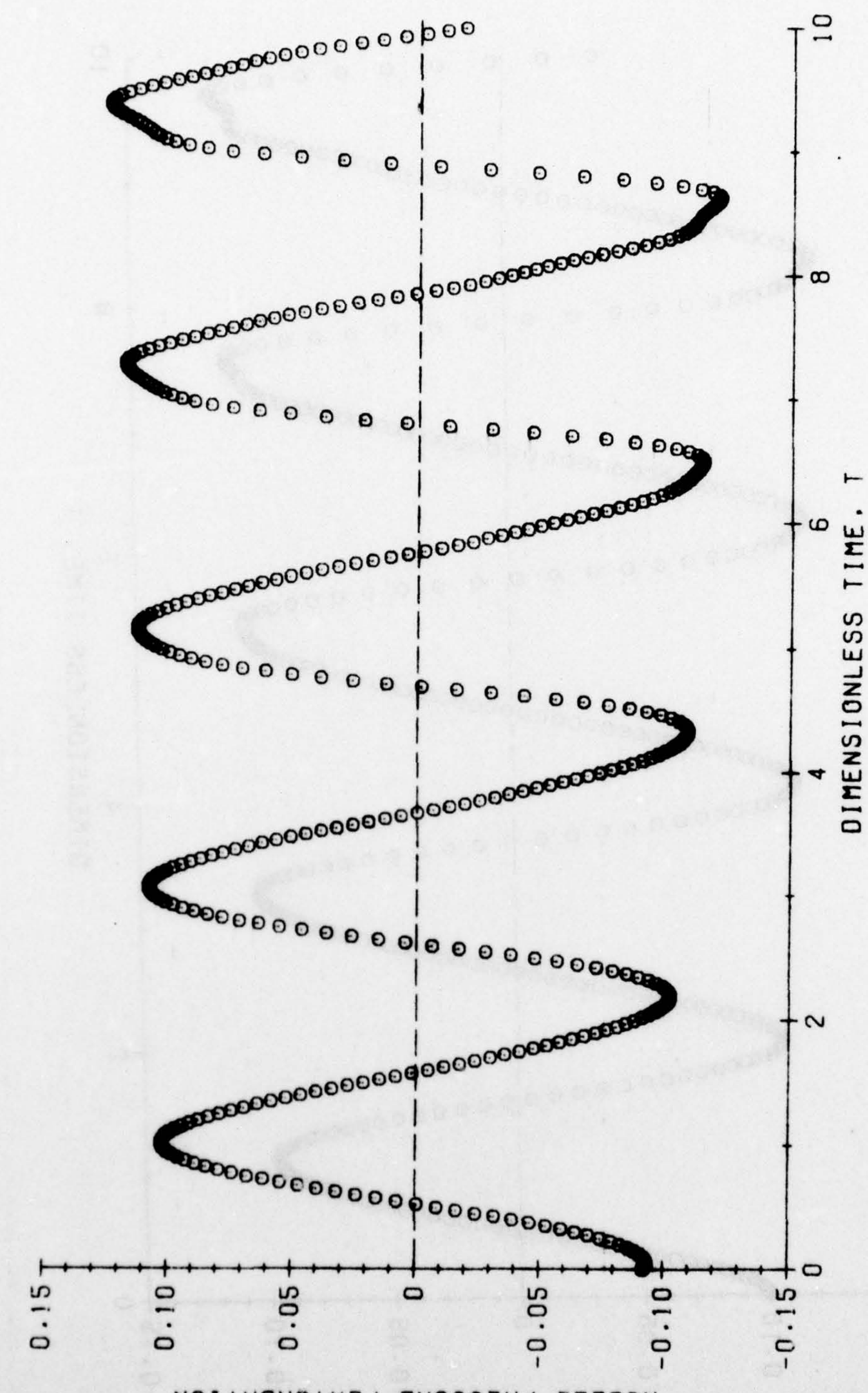
PRESSURE MAXIMA AND MINIMA AT: Z = 0.00
VALUES COMPUTED: 11

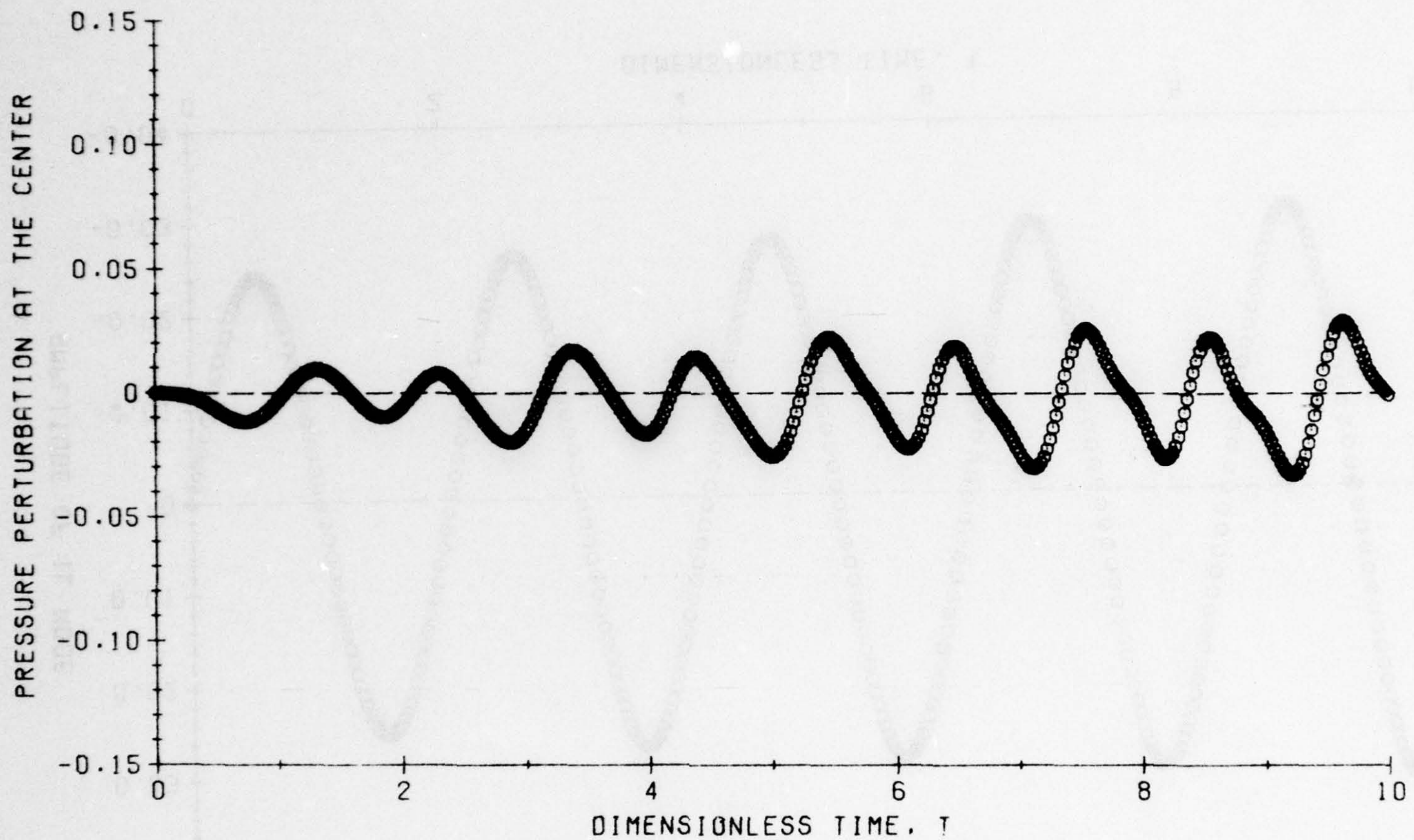
-.096754	.107214	-.102947	.113080	-.107641	.117706	-.113110	.123180
1.132498	2.046082	3.281713	4.115445	5.438972	6.221587	7.589823	8.340012
-.109556	-.109268	-.119232					
9.473120	9.520657	9.710299					

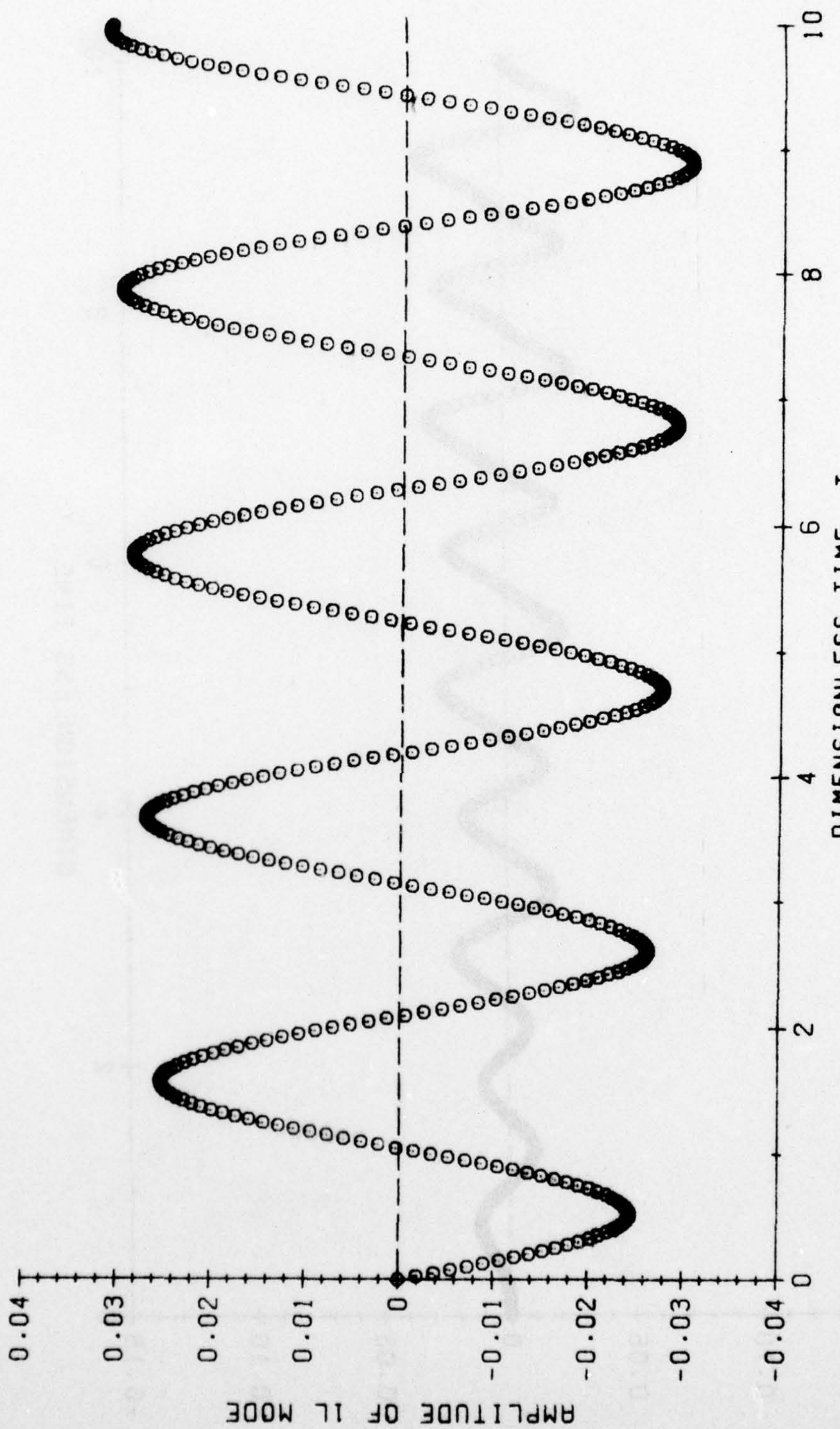
PRESSURE GROWTH RATE AND FREQUENCY.
TOTAL NUMBER OF CYCLES: 3

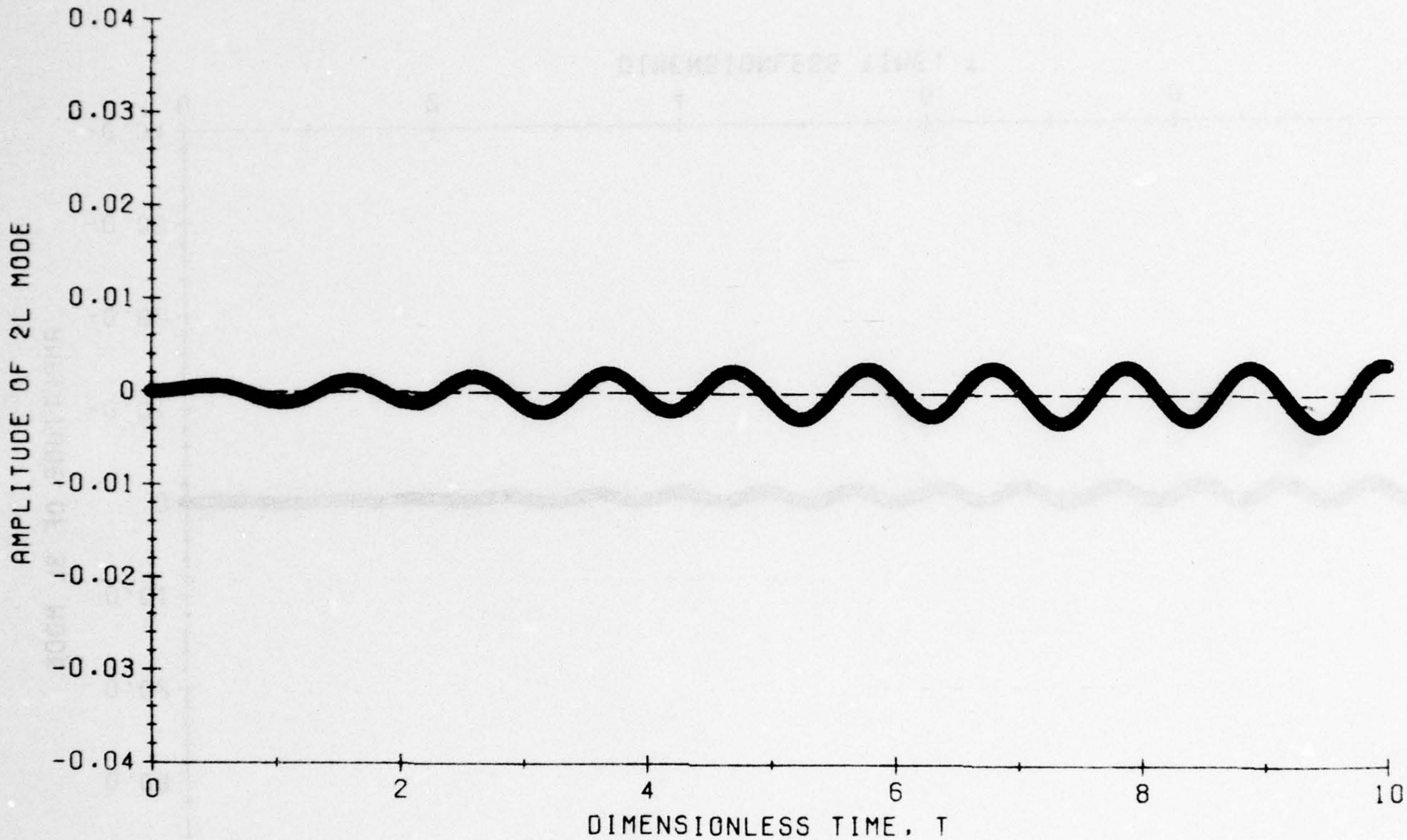
55.137343	40.774533	45.965380
1035.101106	1017.025567	1011.128537
3.080763	5.166516	7.280799

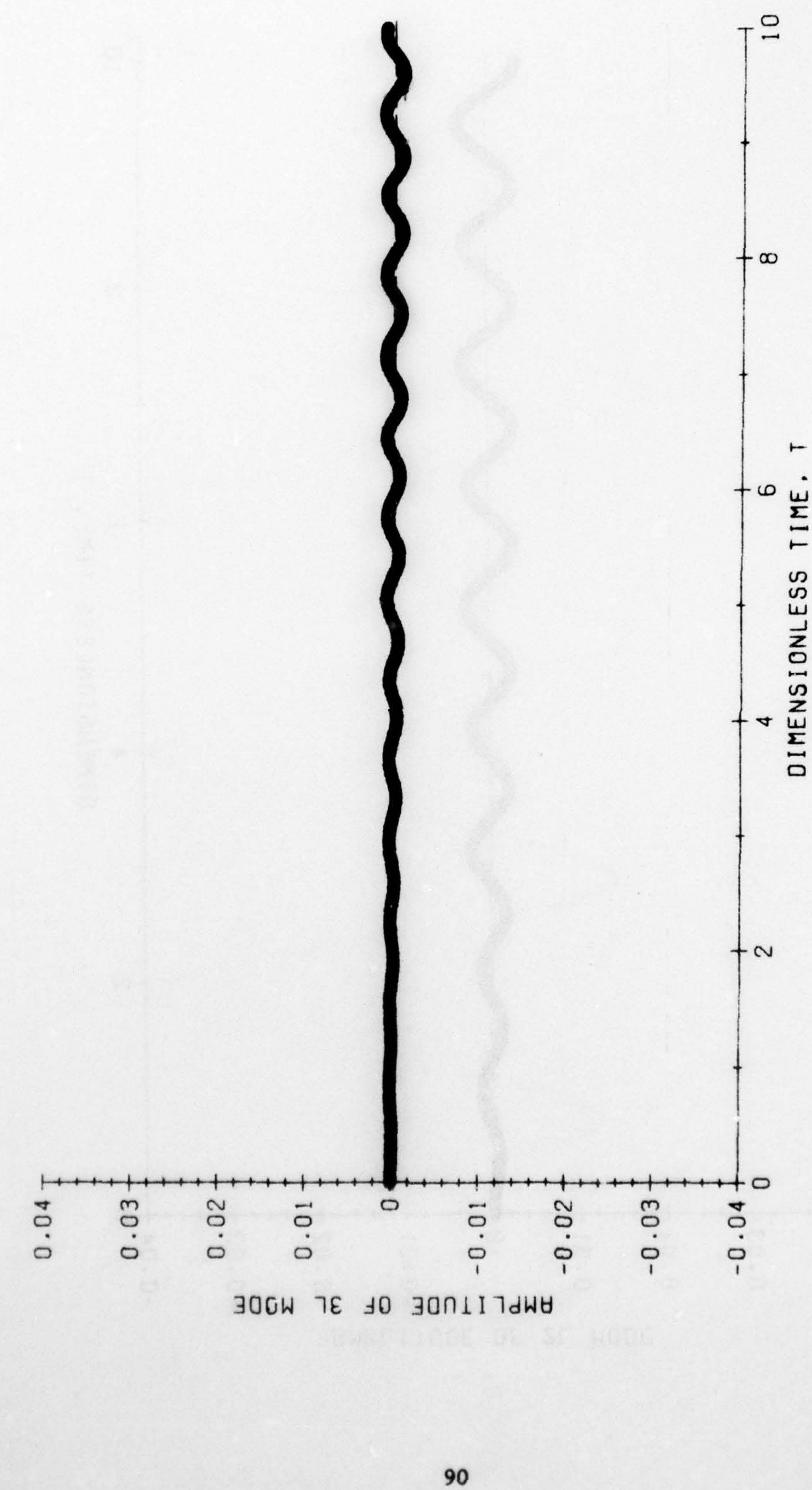

HEAD-END PRESSURE PERTURBATION
0.15
0.10
0.05
0
-0.05
-0.10
-0.15
0
2
4
6
8
10
DIMENSIONLESS TIME, τ


NOZZLE PRESSURE PERTURBATION
0.15
0.10
0.05
0
-0.05
-0.10
-0.15
0
2
4
6
8
10
DIMENSIONLESS TIME, T


PRESSURE PERTURBATION AT THE CENTER
0.15
0.10
0.05
0
-0.05
-0.10
-0.15
0
2
4
6
8
10
DIMENSIONLESS TIME, T


AMPLITUDE OF 1L MODE
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
0
2
4
6
8
10
DIMENSIONLESS TIME, T

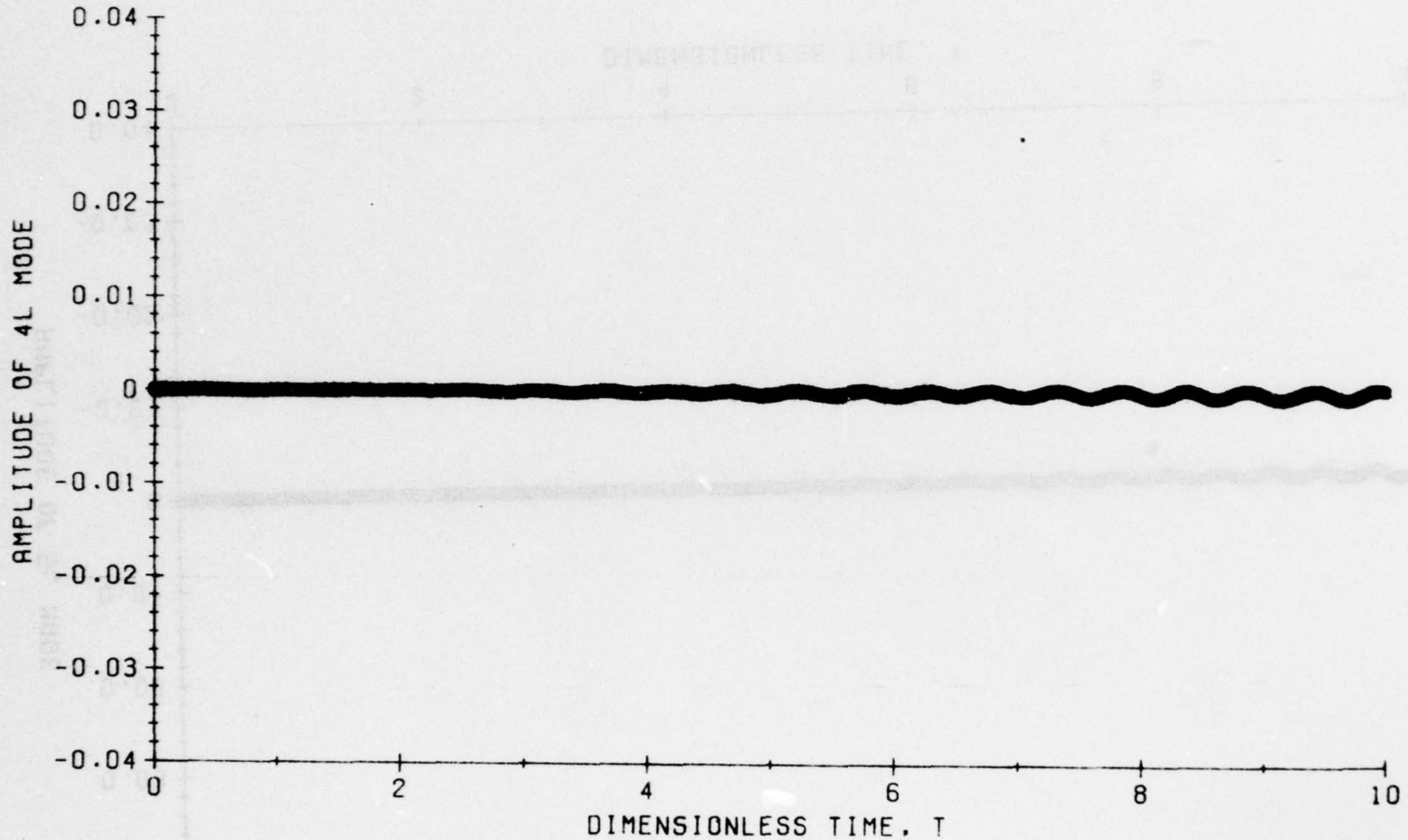

0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
AMPLITUDE OF 2L MODE
0
2
4
6
8
10
DIMENSIONLESS TIME, T

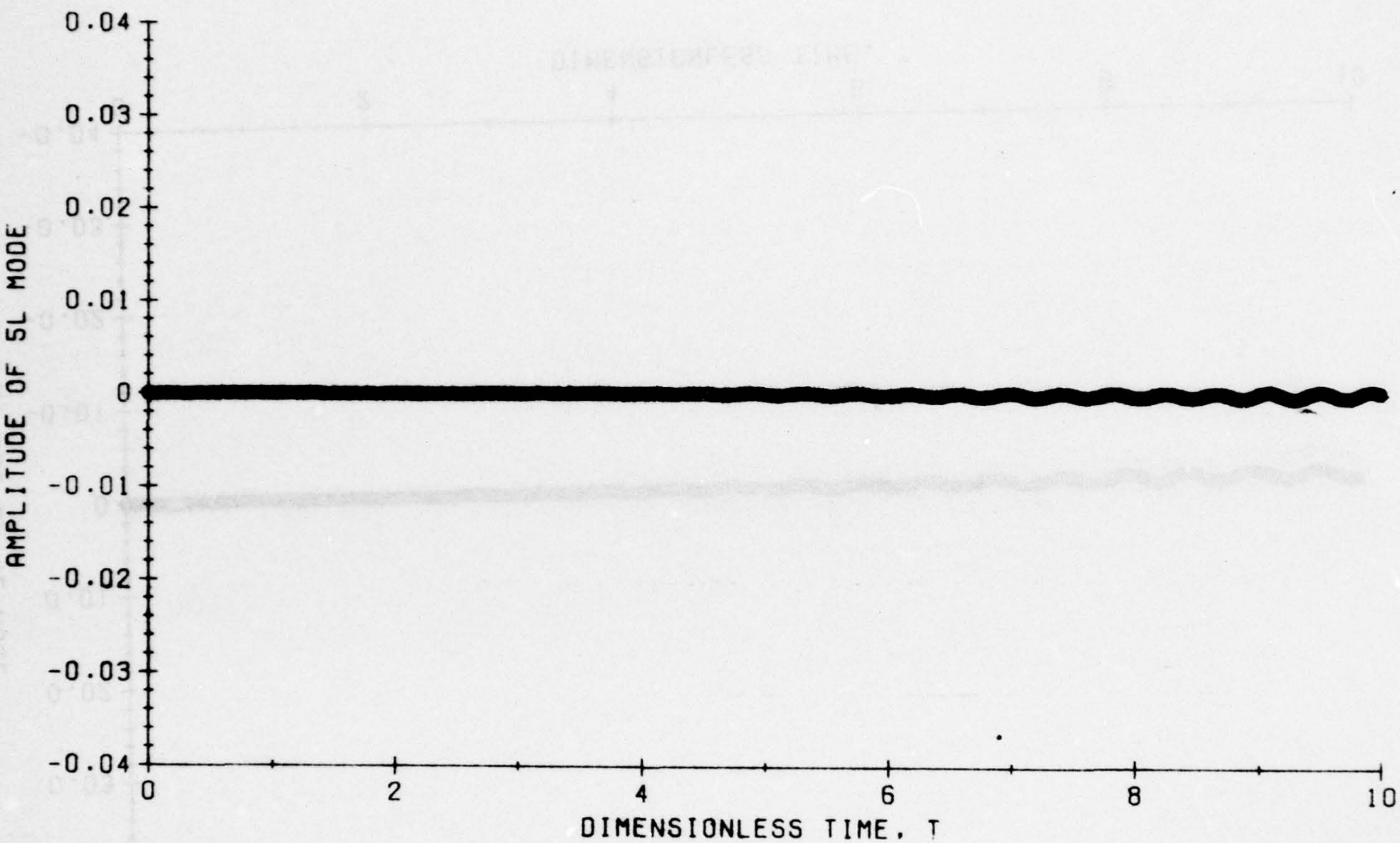

AMPLITUDE OF 3L MODE
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
0
2
4
6
8
10
DIMENSIONLESS TIME, T

AD-A045 118 GEORGIA INST OF TECH ATLANTA SCHOOL OF AEROSPACE ENG--ETC F/G 21/8.2
APPROXIMATE NONLINEAR ANALYSIS OF SOLID ROCKET MOTORS AND T-BUR--ETC(U)
JUL 77 E A POWELL, M S PADMANABHAN, B T ZINN F04611-75-C-0036

UNCLASSIFIED AFRPL-TR-77-48-VOL-2 NL

2 OF 4
AD
A045118


AMPLITUDE OF 4L MODE
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
0
2
4
6
8
10
DIMENSIONLESS TIME, T


0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
AMPLITUDE OF SL MODE
0
2
4
6
8
10
DIMENSIONLESS TIME, T

FORTRAN Source Code.

```
      PROGRAM SOLID2(INPUT,OUTPUT,DATA,
     1              TAPE5=INPUT,TAPE6=OUTPUT,TAPE9=DATA)
C
C
C     *************** PROGRAM SOLID2 ********************************
C
C
C        THIS PROGRAM INTEGRATES THE SYSTEM OF DIFFERENTIAL EQUATIONS
C     FOR MODE AMPLITUDES USING THE COEFFICIENTS COMPUTED BY THE
C     PROGRAM SOLID1. TIME-HISTORY OF A PRESSURE DISTURBANCE IN THE
C     ROCKET IS COMPUTED, AND THE DESIRED PLOTS & PRINTOUTS ARE
C     PRODUCED.
C
C
C     THE FOLLOWING INPUTS ARE REQUIRED:
C     (1)  THE CONTROL NUMBERS, NOUTCF AND NHISTR.
C     (2)  THE COEFFICIENTS FROM PROGRAM SOLID1.
C     (3)  THE DATA DECK.
C
C     THE FIRST CARD GIVES THE CONTROL NUMBERS, NOUTCF AND NHISTR.
C        NOUTCF DETERMINES PRINTOUT OF COEFFICIENTS:
C           IF NOUTCF = 0  COEFFICIENTS ARE NOT PRINTED OUT.
C           IF NOUTCF = 1  ONLY LINEAR COEFFICIENTS ARE PRINTED OUT.
C           IF NOUTCF = 2  ALL COEFFICIENTS ARE PRINTED OUT.
C        NHISTR DETERMINES IF PRESSURE HISTORY IS TO BE PRINTED:
C           IF NHISTR = 0  PRINTED
C           IF NHISTR = 1  NOT PRINTED.
C
C     THE COEFFICIENTS ARE OBTAINED FROM PROGRAM SOLID1
C     BY PUTTING NOUT = 1 OR NOUT = 2, THEREBY WRITING THE COEFFICIENTS
C     INTO A DISK. THIS DISK HAS BEEN GIVEN THE DEVICE NUMBER 9.
C
C     THE DATA DECK CONSISTS OF THE FOLLOWING CARDS:
C
C     FIRST CARD: TITLE OF THE CASE.
C
C     SECOND CARD: H, TSTART, TQUIT, FREQ, BCOMB
C        H IS THE INTEGRATION STEP SIZE.
C        TSTART IS THE TIME AT WHICH OUTPUT STARTS.
C        TQUIT IS THE TIME AT WHICH COMPUTATIONS ARE TERMINATED.
C        FREQ IS THE MOTOR FREQUENCY (IN PURE GAS), IN HERTZ.
C        BCOMB IS THE COMBUSTION RESPONSE NONLINEARITY FACTOR.
C
C     THIRD CARD: A2PARA, B2PARA, EN, OMEGA
C        A2PARA AND B2PARA ARE THE COMBUSTION PARAMETERS IN THE A-B MODEL.
C        EN IS THE PRESSURE EXPONENT IN THE BURNING RATE LAW.
C        OMEGA IS THE FREQUENCY NONDIMENSIONALIZED BY THE SQUARE OF
C        THE STEADY-STATE BURNING RATE.
C
C     FOURTH CARD: NLOC, NTERMS, NOUT, NCOMB, NNPRT
```

```
C         NLOC DETERMINES THE LOCATION OF THE WALL PRESSURE MAXIMA
C         AND MINIMA:
C             IF NLOC = 1     LOCATION IS Z = 0.0
C             IF NLOC = 2     LOCATION IS Z = 1.0
C             IF NLOC = 3     LOCATION IS Z = 0.5
C         NTERMS IS THE NUMBER OF TERMS GIVEN INITIAL VALUES.
C         NOUT IS THE OUTPUT CONTROL NUMBER.
C             IF NOUT = 0     PRINTED OUTPUT ONLY.
C             IF NOUT > 0     BOTH PRINTED AND PLOTTED OUTPUT:
C             IF NOUT = 1     PLOT OF PRESSURE AT Z = 0.0 ONLY.
C             IF NOUT = 2     PLOT OF PRESSURE AT Z = 0.0 AND Z = 1.0
C             IF NOUT = 3     PLOT OF PRESSURE AT Z = 0.0, 1.0 AND 0.5.
C         NCOMB DETERMINES IF COMBUSTION NONLINEARITIES ARE CONSIDERED:
C             IF NCOMB = 0     NEGLECTED.
C             IF NCOMB = 1     INCLUDED.
C         NNPRT DETERMINES IF NONLINEAR PARTICLE DAMPING IS CONSIDERED:
C             IF NNPRT = 0     NOT CONSIDERED.
C             IF NNPRT = 1     CONSIDERED.
C
C      NEXT CARD (NECESSARY ONLY IF NNPRT = 1): REFPRS, CPGAS, CNLP
C          REFPRS IS THE CHAMBER PRESSURE, IN PSI.
C          CPGAS IS THE SPECIFIC HEAT AT CONSTANT PRESSURE OF THE
C          GAS PHASE, IN CAL/GM-DEG K.
C          CNLP IS THE COEFFICIENT IN THE AMPLITUDE-DEPENDENT
C          PART OF THE NONLINEAR PARTICLE DRAG.
C
C     NEXT CARD (NECESSARY ONLY IF PLOTS ARE REQUIRED): YHI, YLAB, ITICY
C         YHI IS THE MAXIMUM ORDINATE FOR PRESSURE PLOTS.
C         NOTE: THE ORDINATE SCALES FOR PRESSURE AND AMPLITUDE PLOTS
C               ARE SYMMETRIC ABOUT ZERO.
C         YLAB IS THE INTERVAL FOR ORDINATE LABELING FOR ABOVE PLOTS.
C         ITICY IS THE NUMBER OF ORDINATE TIC MARKS FOR ABOVE PLOTS.
C         NOTE: ITICY SHOULD BE NEGATIVE FOR PRESSURE AND AMPLITUDE PLOTS
C               TO OBTAIN CENTERLINE.
C
C     NEXT CARD (NECESSARY ONLY IF PLOTS ARE REQUIRED): MDPLOT
C         MDPLOT DETERMINES IF PLOTS OF INDIVIDUAL MODES ARE REQUIRED:
C             IF PLOT OF J TH MODE IS REQUIRED, PUNCH "1" IN THE
C             5*J TH COLUMN.
C             IF PLOT OF J TH MODE IS NOT REQUIRED, PUNCH "0" IN THE
C             5*J TH COLUMN.
C
C     NEXT CARD (NECESSARY ONLY IF PLOT OF ANY MODE AMPLITUDE IS
C     REQUIRED): YHIMD, YLABMD, ITICMD
C         YHIMD IS THE MAXIMUM ORDINATE.
C         YLABMD IS THE INTERVAL FOR ORDINATE LABELLING.
C         ITICMD IS THE NUMBER OF ORDINATE TIC MARKS FOR MODE PLOTS.
C         NOTE: ITICMD SHOULD BE NEGATIVE TO OBTAIN CENTERLINE.
C
C     REMAINING CARDS (NTERMS IN NUMBER): J, AST, ACT
C         AST IS THE AMPLITUDE OF THE SINE TERM OF THE J TH MODE.
C         ACT IS THE AMPLITUDE OF THE COSINE TERM OF THE J TH MODE.
C
```

```
C     ******************************************************************
C
C
      COMPLEX      YNOZ(6), B(6), C1, C3, RES(6), CRES
      DIMENSION    L(6), NAME(6), AA(4), FRQ1(24),
     1             YI(12), YR(12), E(12,12,2),
     2             CFT(3,12), CFZ(3,12), AS(24),
     3             AC(24), U(5,36), Y(36),PRESS(3),
     4             YP(36), FZ(4,36), UZ(36),Z(3), TIMAX(500),
     5             TPLOT(500), YPLOT(3,500), DUMMYT(500), DUMMYY(500),
     6             IBUF(512), ITT(3), ITY1(3),ITY2(3),ITY3(4),
     7             TITLE(7), PRS(500), TI(500), PMAX(500),
     8             MDPLOT(6), UPLOT(6,500), MTITL1(2), MTITL2(2),
     9             MTITL3(2), MTITL4(2), MTITL5(2), MTITL6(2), MTITL(2)
C
      COMMON       C(2,12,24), D(12,144), CP(3,12,24),
     1             KPMAX(3,12), IC(2,12,24), CPPAR(2,12,24),
     2             KPQMAX(12), IDP(12,144), IDQ(12,144), CPAR(12,24)
      COMMON       /BLK2/       B
      COMMON       /BLK3/       NPRTKL, NJMAX, NLMAX  GAMMA,
     1                          COEF(2,12), NJMAX2
      COMMON       /BLK4/       CM, PARTKL, RHOP
      COMMON       /BLK5/       RES, NCOMB, BCOMB, E
      COMMON       /BLK7/       NNPRT, CNNPRT
C
      DATA    ITT/"DIMENSIONL","ESS TIME, ","T         "/,
     1        ITY1/"HEAD-END P","RESSURE PE","RTURBATION"/,
     2        ITY2/"NOZZLE PRE","SSURE PERT","URBATION  "/,
     3        ITY3/"PRESSURE P","ERTURBATIO","N AT THE C","ENTER     "/,
     4        MTITL1/"AMPLITUDE ","OF 1L MODE"/,
     5        MTITL2/"AMPLITUDE ","OF 2L MODE"/,
     6        MTITL3/"AMPLITUDE ","OF 3L MODE"/,
     7        MTITL4/"AMPLITUDE ","OF 4L MODE"/,
     8        MTITL5/"AMPLITUDE ","OF 5L MODE"/,
     9        MTITL6/"AMPLITUDE ","OF 6L MODE"/
C
      MAXMD = 6
      MAXMD2 = 12
      MAXMD4 = 24
      MAXMDD = 144
      LAST = 5
      ERR = 0.001
      TDEL = 10.0
      NPT = 0
      AA(1) = 0.0
      AA(2) = 0.5
      AA(3) = 0.5
      AA(4) = 1.0
      PI = 3.1415926536
      HC = 1.0
      READ (5,5003) NOUTCF, NHISTR
```

```
C
C     ************* COEFFICIENT INPUT SECTION **************************
C
C     THIS VERSION OF SOLID2 READS THE COEFFICIENT DATA FROM
C     A FILE GENERATED BY PROGRAM SOLID1.  TO READ
C     THIS DATA FROM CARDS, USE READ (5,XXXX) INSTEAD OF
C     READ (9,XXXX) IN THIS SECTION.
C
C     INPUT OF MOTOR PARAMETERS AND NUMBER OF TERMS.
      READ (9,5001)  GAMMA, UE, ZE, NJMAX, NPRTKL
      RHOP = 0.0
      PARTKL = 0.0
      PRTSS = 0.0
      UPBYU = 0.0
      JMX = NJMAX/2
      NJMAX2 = NJMAX
      NU = 2 * NJMAX
      GAM = GAMMA
      FRATIO = 1.0
      IF (NPRTKL .EQ. 0) GO TO 14
      READ (9,5011)  DIA, RHOM, SP, TEMP, FREQ, PARTKL, CM
      UPBYU = 2.0 / (1.+ SQRT(1.+8.0*UE/PARTKL))
      RHOP = CM / UPBYU
      GAM = GAMMA / (1.0 + 0.68*CM - 0.68*CM*GAMMA)
      FRATIO = SQRT(GAMMA / (GAM * (1.0 + CM)))
      NJMAX2 = 2*NJMAX
      NU = NJMAX2 + NJMAX
   14 CONTINUE
C
      WRITE (6,6001) UE, JMX, GAM
      IF (NPRTKL .EQ. 0) WRITE (6,6033)
      IF (NPRTKL .EQ. 1) WRITE (6,6009) GAMMA
      IF (NPRTKL .EQ. 1) WRITE (6,6030) DIA, CM, FREQ, TEMP,
     1                   SP, RHOM,PARTKL
      WRITE (6,6002)
C
C     INPUT OF DESCRIPTION OF SERIES EXPANSION.
      DO 10 K = 1, JMX
      READ (9,5002) NJ, L(NJ), NAME(NJ)
      WRITE (6,6003)  NAME(NJ), NJ, L(NJ)
   10 CONTINUE
C
      WRITE (6,6010)
      DO 15 K = 1, JMX
      READ (9,5010) J, YNOZ(J), B(J)
      WRITE (6,6015) J, YNOZ(J), B(J)
      NJ = (2 * J) - 1
      YR(NJ) = REAL(YNOZ(J))
      YI(NJ) = AIMAG(YNOZ(J))
      YR(NJ+1) = YR(NJ)
      YI(NJ+1) = YI(NJ)
   15 CONTINUE
C
```

```
C     ZERO LINEAR COEFFICIENT ARRAYS.
      DO 20 KC = 1, 3
      DO 20 NJ = 1, MAXMD2
      DO 20 NP = 1, MAXMD4
      CP(KC,NJ,NP) = 0.0
   20 CONTINUE
C
C     ZERO NONLINEAR COEFFICIENT ARRAY.
      DO 30 NJ = 1, MAXMD2
      DO 30 NPQ = 1, MAXMDD
      D(NJ,NPQ) = 0.0
   30 CONTINUE
C
C     INPUT OF LINEAR COEFFICIENTS.
      DO 40 KC = 1, 3
      READ (9,5003) KMAX
      IF (NOUTCF .GT. 0) WRITE (6,6004) KC, KMAX
      IF (KMAX .EQ. 0)  GO TO 40
      DO 45 K = 1, KMAX
      READ (9,5004) NJ, NP, CP(KC,NJ,NP)
      IF (NOUTCF .GT. 0) WRITE (6,6005) KC, NJ, NP, CP(KC,NJ,NP)
   45 CONTINUE
   40 CONTINUE
C
      DO 305 KC = 4, 5
      READ (9,5003) KMAX
      KCMIN3 = KC - 3
      IF (NOUTCF .GT. 0) WRITE (6,6031) KCMIN3, KMAX
      IF (KMAX .EQ. 0) GO TO 305
      DO 310 K = 1, KMAX
      READ (9,5004) NJ, NP, E(NJ,NP,KCMIN3)
      IF (NOUTCF .GT. 0) WRITE (6,6032) NJ, NP, KCMIN3, E(NJ,NP,KCMIN3)
  310 CONTINUE
  305 CONTINUE
C
      DO 1040 KC = 1, 2
      READ (9,5003) KMAXPR
      IF (NOUTCF .GT. 0) WRITE (6,6036) KMAXPR
      IF (KMAXPR .EQ. 0) GO TO 1040
      DO 1042 K = 1, KMAXPR
      READ (9,5004) NJ, NP, CPPAR(KC,NJ,NP)
      IF (NOUTCF .GT. 0) WRITE (6,6037) NJ, NP, CPPAR(KC,NJ,NP)
 1042 CONTINUE
 1040 CONTINUE
C
C     INPUT OF NONLINEAR COEFFICIENTS.
      READ (9,5003) NLMAX
      IF (NOUTCF .EQ. 2)  WRITE (6,6006) NLMAX
      IF (NLMAX .EQ. 0)  GO TO 50
      DO 52 NJ = 1, MAXMD2
      KPQMAX(NJ) = 0
   52 CONTINUE
```

```
      DO 55 K = 1, NLMAX
      READ (9,5005)  NJ, NP, NQ, DT
      IF (NOUTCF .EQ. 2)  WRITE (6,6007)  NJ, NP, NQ, DT
      KPQMAX(NJ) = KPQMAX(NJ) + 1
      KPQ = KPQMAX(NJ)
      IDP(NJ,KPQ) = NP
      IDQ(NJ,KPQ) = NQ
      D(NJ,KPQ) = DT
   55 CONTINUE
   50 CONTINUE
C
C     ************* PRESSURE COEFFICIENT SECTION **********************
C
C     CALCULATE SPATIAL COORDINATES FOR PRESSURE COMPUTATION.
      Z(1) = 0.0
      Z(2) = ZE
      Z(3) = 0.5 * ZE
C
C     CALCULATE COEFFICIENTS FOR PRESSURE TIME HISTORIES.
      DO 53 NPRES = 1, 3
      DO 53 J = 1, JMX
      NP = (2 * J) - 1
      Z1 = Z(NPRES)
      CALL PHICFS(J,Z1,C1,C3)
      CFT(NPRES,NP) = REAL(C1)
      CFT(NPRES,NP+1) = -AIMAG(C1)
      CFZ(NPRES,NP) = REAL(C3)
      CFZ(NPRES,NP+1) = -AIMAG(C3)
   53 CONTINUE
C
C     OUTPUT OF COEFFICIENTS FOR PRESSURE TIME HISTORIES.
      WRITE (6,6020)
      DO 56 NPRES = 1, 3
      WRITE (6,6014)
      DO 56 J = 1, NJMAX
      WRITE (6,6021) J, Z(NPRES), CFT(NPRES,J), CFZ(NPRES,J)
   56 CONTINUE
C
C     ************* DATA INPUT SECTION ********************************
C
      READ (5,5000) TITLE
C
C     ZERO INITIAL VALUE AND FREQUENCY ARRAYS.
    5 DO 57 K = 1, NJMAX2
      AS(K) = 0.0
      AC(K) = 0.0
      FRQ1(K) = 0.0
   57 CONTINUE
C
C
```

```
C     READ COMBUSTION AND CONTROL PARAMETERS.
      READ (5,5006) H, TSTART, TQUIT, FREQ, BCOMB
      IF (EOF(5)) 300, 1
    1 CONTINUE
      READ (5,5013) A2PARA, B2PARA, EN, OMEGA
      WRITE (6,6034) A2PARA, B2PARA, EN, OMEGA
      DO 46 K = 1, JMX
      OMEGAK = OMEGA * K
      CALL RESPNS(EN,A2PARA,B2PARA,OMEGAK,CRES)
      RES(K) = CRES
      WRITE (6,6035) K, RES(K)
   46 CONTINUE
C
C     READ CONTROL NUMBERS.
      READ (5,5008)  NLOC, NTERMS, NOUT, NCOMB, NNPRT
      IF (NOUT .GT. 0)  NPT = 1
      IF (NCOMB .EQ. 0) WRITE (6,6039)
      IF (NCOMB .EQ. 1) WRITE (6,6040) BCOMB
      IF (NNPRT .EQ. 0) WRITE (6,6041)
      IF (NNPRT .EQ. 0) GO TO 11
      READ (5,5013) REFPRS, CPGAS, CNLP
      VISC = 8.834 * 0.00001 * (TEMP/3485.)**0.66
      REYN = ((0.00010655765 * GAM * REFPRS * DIA) / (VISC
     1        * SQRT((GAM-1.0) * CPGAS * TEMP))) **(2./3.) / 6.0
      WRITE (6,6038) REFPRS, CPGAS, REYN
   11 CONTINUE
C
C
      IF (NOUT .EQ. 0)  GO TO 9
C     READ DATA FOR SETTING UP PLOTS.
      READ (5,5009) YHI, YLAB, ITICY
      READ (5,5014) MDPLOT
      MDPLTL = 0
      DO 320 K = 1, JMX
  320 MDPLTL = MDPLTL + MDPLOT(K)
      IF (MDPLTL .EQ. 0) GO TO 9
      READ (5,5015) YHIMD, YLABMD, ITICMD
      YLOMD = - YHIMD
C
C     ************* INITIAL AMPLITUDES SECTION ****************************
C
    9 DO 54 K = 1, NTERMS
C
C     INPUT INITIAL AMPLITUDES FOR F-FUNCTIONS.
      READ (5,5007)  J, AST, ACT
      NJ = (2 * J) - 1
      AS(NJ) = AST
      AC(NJ) = ACT
C
C     CALCULATE FREQUENCY.
      AX = L(J) * PI * FRATIO/ZE
      FRQ1(NJ) = AX
      FRQ1(NJ+1) = FRQ1(NJ)
```

```
C
C     CALCULATE INITIAL AMPLITUDES FOR G-FUNCTIONS.
C
      IF (FRQ1(NJ)) 58, 58, 581
  581 GYRU = GAMMA*YR(NJ)*UE
      GYIF = GAMMA*YI(NJ)*FRQ1(NJ)
      GYRF = GAMMA*YR(NJ)*FRQ1(NJ)
      GYIU = GAMMA*YI(NJ)*UE
C
      NPRES = 2
C
      A1 = (1.0 + GYRU)*CFZ(NPRES,NJ+1)
     1      - GYIF*CFT(NPRES,NJ+1)
      A2 = GYRF*CFT(NPRES,NJ+1) + GYIU*CFZ(NPRES,NJ+1)
      A3 = -(1.0 + GYRU)*CFZ(NPRES,NJ) + GYIF*CFT(NPRES,NJ)
      A4 = GYRF*CFT(NPRES,NJ) + GYIU*CFZ(NPRES,NJ)
C
      DET = A1*A1 + A2*A2
      IF (DET .LT. 0.0000001) GO TO 583
      R1 = A3*AC(NJ) - A4*AS(NJ)
      R2 = -A4*AC(NJ) - A3*AS(NJ)
C
      AC(NJ+1) = (R1*A1 + R2*A2)/DET
      AS(NJ+1) = -(R2*A1 - R1*A2)/DET
      GO TO 58
  583 AC(NJ+1) = -AS(NJ)
      AS(NJ+1) = AC(NJ)
C
   58 CONTINUE
      IF (NPRTKL .EQ. 0) GO TO 54
      AS(NJ+NJMAX) = AS(NJ)
      AC(NJ+NJMAX) = AC(NJ)
      AS(NJ+1+NJMAX) = AS(NJ+1)
      AC(NJ+1+NJMAX) = AC(NJ+1)
   54 CONTINUE
C
C
C     OUTPUT OF INITIAL AMPLITUDES.
      WRITE (6,6016)
      DO 590 J = 1, NJMAX
      IF (AS(J))    591, 592, 591
  592 IF (AC(J))    591, 590, 591
  591 WRITE (6,6017) J, FRQ1(J), AC(J), AS(J)
  590 CONTINUE
      IF (NOUT .GE. 1)  WRITE (6,6027)
C
C     ************* LINEAR COEFFICIENTS SECTION ************************
C
      DO 59 KC = 1, 3
      DO 59 NJ = 1, MAXMD2
      KPMAX(KC,NJ) = 0
   59 CONTINUE
```

```
C
      DO 315 KC = 1, 2
      DO 315 NJ = 1, MAXMD2
      DO 315 NP = 1, MAXMD4
      C(KC,NJ,NP) = 0.0
  315 CONTINUE
C
      IF (NNPRT .EQ. 0) GO TO 410
      UMINUP = UE * (1.0 - UPBYU)
      IF (UMINUP .LT. 0.0000001) GO TO 410
      PRTSS = 0.6 * REYN * UMINUP **(2./3.)
      CNNPRT = PARTKL * REYN * CNLP
  410 CONTINUE
C
C     COMPUTE LINEAR COEFFICIENTS FOR GIVEN VALUES OF
C     HC AND RESPONSE FUNCTION.
      DO 60 NJ = 1, NJMAX
      DO 60 NP = 1, NJMAX2
      CT = CP(1,NJ,NP)
      IF (CT) 61, 62, 61
   61 KPMAX(1,NJ) = KPMAX(1,NJ) + 1
      KP = KPMAX(1,NJ)
      IC(1,NJ,KP) = NP
      C(1,NJ,KP) = CT
   62 CONTINUE
      IF (NP .GT. NJMAX .OR. NJ .GT. NJMAX) GO TO 316
      NP12 = (NP+1)/2
      RESR = REAL (RES(NP12))
      RESI = AIMAG (RES(NP12))
      CT = CP(2,NJ,NP) + PARTKL * (1.0 + PRTSS) * CP(3,NJ,NP)
     1      + HC*RESR*E(NJ,NP,1) + HC*RESI*E(NJ,NP,2)
      GO TO 318
  316 CONTINUE
      CT = CP(2,NJ,NP) + PARTKL * (1.0 + PRTSS) * CP(3,NJ,NP)
  318 CONTINUE
      IF(CT) 63, 60, 63
   63 KPMAX(2,NJ) = KPMAX(2,NJ) + 1
      KP = KPMAX(2,NJ)
      IC(2,NJ,KP) = NP
      C(2,NJ,KP) = CT
   60 CONTINUE
C
      IF (NPRTKL .EQ. 0) GO TO 415
      DO 420 NJ = 1, NJMAX
      DO 420 NP = 1, NJMAX2
      CPAR(NJ,NP) = CPPAR(1,NJ,NP) +
     1              PARTKL * (1.0 + PRTSS) * CPPAR(2,NJ,NP)
  420 CONTINUE
  415 CONTINUE
C
```

```
C     ************** INITIAL VALUES SECTION *******************************
C
      NSTEP = 0
      NP1 = 3
      H6 = H/6
      TIME = 0.0
      I = NP1
      TI(I) = TIME
C
      DO 75 J = 1, NJMAX2
      JP = J + NJMAX2
      IF (AC(J)) 751, 753, 751
  753 IF (AS(J)) 751, 752, 751
  752 U(I,J) = 0.0
      IF (JP .GT. NU) GO TO 75
      U(I,JP) = 0.0
      GO TO 75
  751 ARG = FRQ1(J) * TIME
      FSIN = SIN(ARG)
      FCOS = COS(ARG)
      U(I,J) = AS(J)*FSIN + AC(J)*FCOS
      IF (JP .GT. NU) GO TO 75
      U(I,JP) = ((AS(J) * FCOS) - (AC(J) * FSIN)) * FRQ1(J)
   75 CONTINUE
C     CALCULATE INITIAL VALUES OF PRESSURE AND VELOCITY.
      DO 704 NPRES = 1, 3
      DO 702 J = 1, NJMAX
      COEF(1,J) = CFT(NPRES,J)
      COEF(2,J) = CFZ(NPRES,J)
  702 CONTINUE
      DO 703 J = 1, NU
      Y(J) = U(I,J)
  703 CONTINUE
      UBAR = UE * Z(NPRES)
      UMS = UE
      CALL PRSVEL(UBAR,UMS,Y,P,VZGAS,VZPAR)
      PRESS(NPRES) = P
  704 CONTINUE
      PRS(I) = PRESS(NLOC)
   70 CONTINUE
C
      IF (NHISTR .EQ. 0) WRITE (6,6008) GAM, UE
      IF (NHISTR .EQ. 0) WRITE (6,6022)
C
C     ************** INITIALIZE CONTROL NUMBERS **************************
C
      LINE = 8
      K = 0
      MAXNO = 0
      MAXP = 0
      IF (NOUT .EQ. 0)  GO TO 100
      JPLOT = 0
```

```
      TMIN = TSTART
      TMAX = TSTART + TDEL
      YLO = -YHI
C
C     ************** NUMERICAL CALCULATIONS SECTION ********************
C
  100 I = NP1
C
C     RUNGE-KUTTA INTEGRATION SCHEME.
  105 NSTEP = I - NP1 + (LAST - NP1) * K
      RSTEP = NSTEP
      TIME = RSTEP * H
      TI(I) = TIME
      DO 120 J = 1, NU
      Y(J) = U(I,J)
  120 CONTINUE
      CALL RHS(Y,YP)
      DO 130 J = 1, NU
      FZ(1,J) = YP(J)
  130 CONTINUE
      DO 140 II = 2,4
      DO 144 J = 1, NU
      UZ(J) = Y(J) + AA(II) * H * FZ(II-1,J)
  144 CONTINUE
      CALL RHS(UZ,YP)
      DO 148 J = 1, NU
      FZ(II,J) = YP(J)
  148 CONTINUE
  140 CONTINUE
      DO 150 J = 1, NU
      U(I+1,J) = Y(J) + (FZ(1,J)+2.0*(FZ(2,J)+FZ(3,J)) + FZ(4,J)) * H6
  150 CONTINUE
C
C     CALCULATE PRESSURE TIME HISTORIES.
      DO 154 NPRES = 1, 3
      DO 152 J = 1, NJMAX
      COEF(1,J) = CFT(NPRES,J)
      COEF(2,J) = CFZ(NPRES,J)
  152 CONTINUE
      UBAR = UE * Z(NPRES)
      UMS = UE
      CALL PRSVEL(UBAR,UMS,Y,P,VZGAS,VZPAR)
      PRESS(NPRES) = P
  154 CONTINUE
      PRS(I) = PRESS(NLOC)
      IF (K .EQ. 0) GO TO 175
C
C     DETERMINE MAXIMUM AND MINIMUM PRESSURE AT LOCATION SPECIFIED
C     BY NLOC.
      DPL = PRS(I) - PRS(I-1)
      DPS = PRS(I-1) - PRS(I-2)
```

```
      IF (DPL*DPS) 173, 173, 175
  173 PNUM = PRS(I-2) - PRS(I)
      PDEN = 2.0 * (PRS(I-2) + PRS(I) - 2.0*PRS(I-1))
      IF (PDEN) 174, 175, 174
  174 PP = PNUM/PDEN
      PA = (PP - 1.0) * PP * 0.5
      PB = 1.0 - (PP * PP)
      PC = (PP + 1.0) * PP * 0.5
      MAXP = MAXP + 1
      PMAX(MAXP) = PA*PRS(I-2) + PB*PRS(I-1) + PC*PRS(I)
      TIMAX(MAXP) = TI(I-1) + PP*H
      IF (MAXP .GE. 500)  GO TO 250
  175 CONTINUE
C
      IF (TIME .LT. TSTART)  GO TO 155
      IF (NOUT .EQ. 0) GO TO 156
C
C     ************* TIME HISTORY PLOTTING SECTION ********************
C
      IF (TMAX .GT. TQUIT)  GO TO 156
      IF ((TIME .GT. TMAX) .OR. (JPLOT .GE. 500))  GO TO 1000
C
      JPLOT = JPLOT + 1
C
C     FILL TIME ARRAY FOR PLOTTING.
      TPLOT(JPLOT) = TIME
C
C     FILL PRESSURE ARRAYS FOR PLOTTING.
      DO 1001 J = 1,3
      YPLOT(J,JPLOT) = PRESS(J)
 1001 CONTINUE
C
C
      IF (MDPLTL .EQ. 0) GO TO 156
C     FILL MODE AMPLITUDE ARRAYS FOR PLOTTING.
      DO 322 J = 1, JMX
      IF (MDPLOT(J) .EQ. 0) GO TO 322
      J12 = 2*J - 1
      UPLOT(J,JPLOT) = U(I,J12)
  322 CONTINUE
C
      GO TO 156
C
 1000 NUM = JPLOT
C
C     PLOT TIME HISTORIES.
C
      DO 1020 NPLOT = 1, NOUT
C
      JPLOT = 0
C
```

```
C       ASSIGN PLOTTING PARAMETERS.
        YMIN = YLO
        YMAX = YHI
        NTICY = ITICY
        DELY = YLAB
C
C       ELIMINATE POINTS THAT ARE OUT OF THE ORDINATE RANGE.
        DO 1010 J = 1, NUM
        IF ((YPLOT(NPLOT,J) .LT. YMIN) .OR. (YPLOT(NPLOT,J) .GT. YMAX))
     1    GO TO 1010
        JPLOT = JPLOT + 1
        DUMMYT(JPLOT) = TPLOT(J)
        DUMMYY(JPLOT) = YPLOT(NPLOT,J)
 1010 CONTINUE
C
        IF (JPLOT .EQ. 0)  GO TO 1020
        GO TO (1011,1014,1015), NPLOT
C
C       PLOT HEAD-END PRESSURE.
 1011 CALL GRAPHS(IBUF,512,4,JPLOT,11,NTICY,TMAX,YMAX,TMIN,YMIN,
     1              ITT,ITY1,21,30,DUMMYT,DUMMYY,2.0,DELY,TITLE)
        GO TO 1020
C
C       PLOT NOZZLE PRESSURE.
 1014 CALL GRAPHS(IBUF,512,4,JPLOT,11,NTICY,TMAX,YMAX,TMIN,YMIN,
     1              ITT,ITY2,21,28,DUMMYT,DUMMYY,2.0,DELY,TITLE)
        GO TO 1020
C
C       PLOT PRESSURE AT THE CENTER (X = 0.5).
 1015 CALL GRAPHS(IBUF,512,4,JPLOT,11,NTICY,TMAX,YMAX,TMIN,YMIN,
     1              ITT,ITY3,21,35,DUMMYT,DUMMYY,2.0,DELY,TITLE)
C
 1020 CONTINUE
C
        DO 324 NPLOT = 1, JMX
        IF (MDPLOT(NPLOT) .EQ. 0) GO TO 324
        JPLOT = 0
        DO 328 J123 = 1, 2
        IF (NPLOT .EQ. 1) MTITL(J123) = MTITL1(J123)
        IF (NPLOT .EQ. 2) MTITL(J123) = MTITL2(J123)
        IF (NPLOT .EQ. 3) MTITL(J123) = MTITL3(J123)
        IF (NPLOT .EQ. 4) MTITL(J123) = MTITL4(J123)
        IF (NPLOT .EQ. 5) MTITL(J123) = MTITL5(J123)
        IF (NPLOT .EQ. 6) MTITL(J123) = MTITL6(J123)
  328 CONTINUE
        DO 326 J = 1, NUM
        IF ((UPLOT(NPLOT,J) .LT. YLOMD) .OR. (UPLOT(NPLOT,J)
     1        .GT. YHIMD)) GO TO 326
        JPLOT = JPLOT + 1
        DUMMYT(JPLOT) = TPLOT(J)
        DUMMYY(JPLOT) = UPLOT(NPLOT,J)
  326 CONTINUE
```

```
      IF (JPLOT .EQ. 0) GO TO 324
      CALL GRAPHS(IBUF,512,4,JPLOT,11,ITICMD,TMAX,YHIMD,TMIN,
     1     YLOMD,ITT,MTITL,21,20,DUMMYT,DUMMYY,2.0,YLABMD,TITLE)
  324 CONTINUE
C
C     REASSIGN PLOTTING PARAMETERS FOR NEXT SET OF PLOTS.
      JPLOT = 0
      TMIN = TMAX
      TMAX = TMAX + TDEL
C
C     ************** TIME HISTORY PRINTED OUTPUT SECTION *****************
C
  156 IF (NHISTR .EQ. 0)
     1     WRITE (6,6011) NSTEP, TIME, (PRESS(J), J = 1,3), VZGAS, VZPAR
      LINE = LINE + 1
  157 IF (TIME .GT. TQUIT)  GO TO 250
      IF (LINE .LT. 52)  GO TO 155
      IF (NHISTR .EQ. 0) WRITE (6,6013)
      IF (NHISTR .EQ. 0) WRITE (6,6022)
      LINE = 4
C
  155 I = I + 1
      IF (I .LT. LAST)  GO TO 105
      K = K + 1
C
C     RE-ASSIGN ARRAYS.
      DO 200 I = 1, NP1
      ILAST = LAST - NP1 + 1
      PRS(I) = PRS(ILAST)
      TI(I) = TI(ILAST)
      DO 200 J = 1, NU
      U(I,J) = U(ILAST,J)
  200 CONTINUE
      GO TO 100
C
C
C     ************** PRESSURE MAXIMA AND MINIMA PRINTOUT *****************
C
  250 WRITE (6,6023) Z(NLOC), MAXP
      LINE = 4
      DO 255 JST = 1, MAXP, 8
      JSTART = JST
      JSTOP = JST + 7
      IF (JSTOP .GT. MAXP) JSTOP = MAXP
      WRITE (6,6024) (PMAX(J), J = JSTART, JSTOP)
      WRITE (6,6024) (TIMAX(J), J = JSTART, JSTOP)
      WRITE (6,6014)
      LINE = LINE + 3
      IF (LINE .LT. 52)  GO TO 255
      LINE = 0
      WRITE (6,6013)
  255 CONTINUE
      CALL GROWTH(MAXP,TIMAX,PMAX,FREQ)
```

```
C
      GO TO 5
  300 CONTINUE
C
C     TURN OFF PLOTTING ROUTINE.
      IF (NPT .EQ. 1)  CALL PLOT(0.0,0.0,999)
C
C     ************* READ FORMAT SPECIFICATIONS *************************
C
 5000 FORMAT (7A10)
 5001 FORMAT (3F10.0,3I5)
 5002 FORMAT (2I5,1X,A4)
 5003 FORMAT (2I5)
 5004 FORMAT (2I5,F15.8)
 5005 FORMAT (3I5,F15.8)
 5006 FORMAT (7F10.0)
 5007 FORMAT (I5,2F10.0)
 5008 FORMAT (6I5)
 5009 FORMAT (2F10.0,I5)
 5010 FORMAT (I5,4F12.8)
 5011 FORMAT (7F15.8)
 5013 FORMAT (4F10.0)
 5014 FORMAT (6I5)
 5015 FORMAT (2F10.0,I5)
 5016 FORMAT (2F10.0)
C
C     ************* WRITE FORMAT SPECIFICATIONS ************************
C
 6001 FORMAT (1H1,//,6X,4HUE =,F6.4,//,6X,17HNUMBER OF MODES =,
     1        I2,//,6X,7HGAMMA =,F5.2)
 6002 FORMAT (//////,6X,14HNAME     J    L/)
 6003 FORMAT (6X,A4,2I5)
 6004 FORMAT (1H0,26H NUMBER OF COEFFICIENTS C(,I1,10H,NJ,NP) IS,I5/)
 6005 FORMAT (2X,2HC(,I1,1H,,I2,1H,,I2,4H) = ,F10.5)
 6006 FORMAT (1H0,38H NUMBER OF COEFFICIENTS D(NJ,NP,NQ) IS,I5/)
 6007 FORMAT (2X,2HD(,I2,1H,,I2,1H,,I2,4H) = ,F10.5)
 6008 FORMAT (1H1,2X,17HMOTOR PARAMETERS:,15X,
     1        8HGAMMA = ,F4.2,10X,19HEXIT MACH NUMBER = ,F7.5//)
 6009 FORMAT (/,6X,10HGAMMABAR =,F9.6,//)
 6010 FORMAT (1H0,////,6X,1HJ,7X,2HYR,8X,2HYI,7X,3HEPS,7X,3HETA//)
 6011 FORMAT (2X,I5,F12.5,5F22.5)
 6013 FORMAT (1H1)
 6014 FORMAT (1H )
 6015 FORMAT (2X,I5,4F10.5)
 6016 FORMAT (1H1,///,1X,36H INITIAL CONDITIONS ARE OF THE FORM://
     1        2X,47HU(I,J) =  AC(J)*COS(FREQ*T) + AS(J)*SIN(FREQ*T),
     2        ////6X,1HJ,6X,9HFREQUENCY,10X,5HAC(J),10X,5HAS(J)//)
 6017 FORMAT (2X,I5,4F15.8/)
 6020 FORMAT (1H1,/,2X,45HCOEFFICIENTS FOR COMPUTATION OF WALL PRESSURE,
     1        10H WAVEFORMS////34X,27HCOEFFICIENTS IN SERIES FOR://
     2        37X,4HTIME,21X,5HAXIAL/6X,1HJ,7X,1HZ,19X,10HDERIVATIVE,
     3        15X,10HDERIVATIVE//)
 6021 FORMAT (2X,I5,F10.3,12X,F15.7,10X,F15.7)
```

```
6022 FORMAT (3X,4HSTEP,8X,4HTIME,15X,8HPRESSURE,14X,8HPRESSURE,14X,
    1        8HPRESSURE,14X,7HGAS VEL,15X,7HPAR VEL,/,34X,
    2        8HAT Z=0.0,14X,8HAT Z=1.0,14X,8HAT Z=0.5,13X,
    3        8HAT Z=0.5,14X,8HAT Z=0.5//)
6023 FORMAT (1H1,38H PRESSURE MAXIMA AND MINIMA AT:    Z = ,F5.2,
    1        /19H VALUES COMPUTED:  ,I3//)
6024 FORMAT (1H ,7X,8F13.6)
6027 FORMAT (2X//2X,33HTHIS RUN PRODUCES PLOTTED OUTPUT.)
6030 FORMAT (///,6X,27HPARTICLE DIA (IN MICRONS) = YF5.1,10X,
    1        4HCM =,F4.2,10X,18HFREQ (IN HERTZ) = ,F6.1,//,
    2        6X,26HCHAMBER TEMP (IN DEG K) = ,F6.1,10X,4HSP =,
    3        F4.2,10X,27HRHOM (IN KG/CUBIC METER) = ,F6.1,//,6X,
    4        27HPARTICLE DRAG CONSTANT, K =,F8.4,////)
6031 FORMAT (1H0,32H NUMBER OF COEFFICIENTS E(NJ,NP,,,I1,4H) IS,I5/)
6032 FORMAT (2X,2HE(,I2,1H,,I2,1H,,I1,4H) = ,F10.5)
6033 FORMAT (/////,6X,26HPARTICLES ARE NOT PRESENT.//)
6034 FORMAT (1H1,///,3X,22HCOMBUSTION PARAMETERS:,5X,3HA =,F6.3,6X,
    1        3HB =,F5.3,5X,4HEN =,F5.3,5X,7HOMEGA =,F6.3,
    2        //////,25X,1HJ,16X,4HRESR,15X,4HRESI,//)
6035 FORMAT (1H0,20X,I5,10X,F10.4,9X,F10.4)
6036 FORMAT (1H0,47HNUMBER OF COEFFICIENTS IN PARTICLE EQUATIONS IS,
    1        I5/)
6037 FORMAT (2X,5HCPAR(,I2,1H,,I2,4H) = ,F10.5)
6038 FORMAT (//////,3X,41HNONLINEAR PARTICLE DAMPING IS CONSIDERED:,
    1        ////,10X,28HCHAMBER PRESSURE (IN PSI) = ,F8.3,//,10X,
    2        46HSPECIFIC HEAT OF GAS PHASE (IN CAL/GM-DEG K) =,
    3        F5.3,//,10X,7HREYN = ,F8.5)
6039 FORMAT (///,3X,27HLINEAR COMBUSTION RESPONSE.)
6040 FORMAT (///,3X,30HNONLINEAR COMBUSTION RESPONSE:,5X,
    1        8HBCOMB = ,F6.3)
6041 FORMAT (/////,3X,24HLINEAR PARTICLE DAMPING.)
     END
```

```
      COMPLEX FUNCTION CCOSH(X)
      COMPLEX X
      CCOSH = 0.5 * (CEXP(X) + CEXP(-X))
      RETURN
      END

      COMPLEX FUNCTION CSINH(X)
      COMPLEX X
      CSINH = 0.5 * (CEXP(X) - CEXP(-X))
      RETURN
      END

      SUBROUTINE PHICFS(NP,Z,CT,CZ)
C
C     THIS SUBROUTINE COMPUTES THE COEFFICIENTS NEEDED TO
C     CALCULATE THE PRESSURE PERTURBATION.
C
C     NP IS THE INDEX OF THE COMPLEX SERIES TERM.
C     Z IS THE AXIAL LOCATION.
C     CT IS THE COEFFICIENT IN THE SERIES FOR THE TIME DERIVATIVE OF
C     THE VELOCITY POTENTIAL.
C
C     CZ IS THE COEFFICIENT IN THE SERIES FOR THE AXIAL DERIVATIVE
C     OF THE VELOCITY POTENTIAL.
C
      COMPLEX    CI, CZ, B(6), CT, CCOSH, CSINH
      COMMON        /BLK2/  B
C
      CI = (0.0,1.0)
      CT = CCOSH(CI * B(NP) * Z)
      CZ = CI * B(NP) * CSINH(CI * B(NP) * Z)
C
      RETURN
      END
```

```
      SUBROUTINE PRSVEL(UBAR, UMS, Y, P, VZGAS, VZPAR)
C
C     THIS SUBROUTINE COMPUTES THE PRESSURE AND VELOCITY.
C
C     UBAR IS THE LOCAL AXIAL STEADY STATE VELOCITY.
C     UMS IS THE DERIVATIVE OF THE VELOCITY.
C     Y IS THE ARRAY CONTAINING VALUES OF THE MODE-AMPLITUDE
C     FUNCTIONS AND THEIR DERIVATIVES.
C     P IS THE VALUE OF THE PRESSURE PERTURBATION.
C     VZGAS IS THE AXIAL COMPONENT OF VELOCITY OF GAS.
C     VZPAR IS THE AXIAL COMPONENT OF PARTICLE VELOCITY.
C
C
      DIMENSION      Y(36), SUM(5), SUMSQ(2)
      COMMON         /BLK3/     NPRTKL, NJMAX, NLMAX, GAMMA,
     1                          COEF(2,12), NJMAX2
      COMMON         /BLK4/     CM, PARTKL, RHOP
C
      DO 10 I = 1, 5
      SUM(I) = 0.0
   10 CONTINUE
C
      DO 20 J = 1, NJMAX
      JY = J + NJMAX2
   20 SUM(1) = SUM(1) + Y(JY) * COEF(1,J)
      DO 50 J = 1, NJMAX
      SUM(2) = SUM(2) + Y(J) * COEF(2,J)
      SUM(3) = SUM(3) + Y(J) * COEF(1,J)
      IF (NPRTKL .EQ. 0) GO TO 50
      JP = J + NJMAX
      SUM(4) = SUM(4) + (Y(J)-Y(JP)) * COEF(1,J)
      SUM(5) = SUM(5) + Y(JP) * COEF(2,J)
   50 CONTINUE
      PLIN = SUM(1) + UBAR * SUM(2) + UMS * SUM(3)
     1         + PARTKL * RHOP * SUM(4)
      PNL = 0.0
      IF (NLMAX .EQ. 0)  GO TO 40
      DO 30 I = 1, 2
      SUMSQ(I) = SUM(I) * SUM(I)
   30 CONTINUE
      PNL = 0.5 * (SUMSQ(2) - SUMSQ(1))
C
   40 P = -GAMMA * (PLIN + PNL)
      VZGAS = SUM(2)
      VZPAR = SUM(5)
C
      RETURN
      END
```

```
      SUBROUTINE RHS(U, UP)
C
C
      COMPLEX       RES(6), RESNL(6)
      DIMENSION     U(36), UP(36), E(12,12,2)
      COMMON        C(2,12,24), D(12,144), CP(3,12,24),
     1              KPMAX(3,12), IC(2,12,24), CPPAR(2,12,24),
     2              KPQMAX(12), IDP(12,144), IDQ(12,144), CPAR(12,24)
      COMMON        /BLK3/    NPRTKL, NJMAX, NLMAX, GAMMA,
     1                        COEF(2,12), NJMAX2
      COMMON        /BLK5/    RES, NCOMB, BCOMB, E
      COMMON        /BLK7/    NNPRT, CNNPRT
C
      IF (NPRTKL .EQ. 0) GO TO 110
      NJS = NJMAX + 1
      DO 112 NJ = NJS, NJMAX2
      NJPAR = NJ - NJMAX
      SLP = 0.0
      DO 114 KP = 1, NJMAX2
      SLP = SLP + (CPAR(NJPAR,KP) * U(KP))
  114 CONTINUE
      UP(NJ) = - SLP
  112 CONTINUE
      IF (NNPRT .EQ. 0) GO TO 110
      DIFF = (U(1) - U(NJS))**2 + (U(2) - U(NJS+1))**2
      IF (DIFF .LT. 0.000000001) GO TO 110
      DIFF13 = CNNPRT * DIFF **(1./3.)
      DO 120 NJ = NJS, NJMAX2
      NJPAR = NJ - NJMAX
      SLNP = 0.0
      DO 125 KP = 1, NJMAX2
      SLNP = SLNP + CPPAR(2,NJPAR,KP) * DIFF13 * U(KP)
  125 CONTINUE
      UP(NJ) = UP(NJ) - SLNP
  120 CONTINUE
  110 CONTINUE
C
      IF (NCOMB .EQ. 0) GO TO 116
      JMX = NJMAX/2
      DO 118 NJ = 1, JMX
      NJPLNJ = 2*NJ
      NJ2MN1 = NJPLNJ - 1
      RESNL(NJ) = RES(NJ) * BCOMB * SQRT (UP(NJ2MN1)**2+UP(NJPLNJ)**2)
  118 CONTINUE
  116 CONTINUE
C
      DO 10 NJ = 1, NJMAX
      NJP = NJ + NJMAX2
      UP(NJ) = U(NJP)
      SL1 = 0.0
      SL2 = 0.0
      SL3 = 0.0
```

```
      SNL1 = 0.0
      SNLC = 0.0
      MAX = KPMAX(1,NJ)
      IF (MAX .EQ. 0) GO TO 25
      DO 20 KP = 1, MAX
      NP = IC(1,NJ,KP)
      SL1 = SL1 + (C(1,NJ,KP) * U(NP))
   20 CONTINUE
   25 MAX = KPMAX(2,NJ)
      IF (MAX .EQ. 0) GO TO 45
      DO 30 KP = 1, MAX
      NP = IC(2,NJ,KP)
      SL2 = SL2 + (C(2,NJ,KP) * UP(NP))
   30 CONTINUE
   45 IF (NLMAX .EQ. 0)  GO TO 55
      MAX = KPQMAX(NJ)
      IF (MAX .EQ. 0) GO TO 55
      DO 50 KPQ = 1, MAX
      NP = IDP(NJ,KPQ)
      NQP = IDQ(NJ,KPQ) + NJMAX2
      SNL1 = SNL1 + (D(NJ,KPQ) * U(NP) * U(NQP))
   50 CONTINUE
   55 CONTINUE
      IF (NCOMB .EQ. 0) GO TO 65
      DO 60 KP = 1, NJMAX
      KP12 = (KP+1)/2
      SNLC = SNLC + (REAL(RESNL(KP12)) * E(NJ,KP,1) +
     1         AIMAG(RESNL(KP12)) * E(NJ,KP,2)) * UP(KP)
   60 CONTINUE
   65 UP(NJP) = -(SL1 + SL2 + SNL1 + SNLC)
   10 CONTINUE
C
      IF (NNPRT .EQ. 0) RETURN
      IF (DIFF .LT. 0.000000001) RETURN
      DIFF13 = CNNPRT * DIFF **(1./3.)
      DO 140 NJ = 1, NJMAX
      NJP = NJ + NJMAX2
      SLNP = 0.0
      DO 145 KP = 1, NJMAX2
      SLNP = SLNP + DIFF13 * CP(3,NJ,KP) * UP(KP)
  145 CONTINUE
      UP(NJP) = UP(NJP) - SLNP
  140 CONTINUE
C
      RETURN
      END
```

```
      SUBROUTINE RESPNS (EN,A,B,OMEGA,RES)
      COMPLEX RES, LAMBDA
      C = (1.0 + 16.*OMEGA*OMEGA)**0.5
      C1 = 0.5 * (1.0 + ((C+1.0)/2.0)**0.5)
      C2 = 0.5 * ((C-1.0)/2.0)**0.5
      LAMBDA = CMPLX(C1,C2)
      RES = (EN*A*B) / (LAMBDA + A/LAMBDA -(1.0+A) + A*B)
      RETURN
      END
```

```
      SUBROUTINE GRAPHS(IBUF,NLOC,LDEV,NTOT,NTICX,NTICY,
     1  XMAX,YMAX,XMIN,YMIN,ITITLX,ITITLY,LTITLX,LTITLY,XARRAY,
     2  YARRAY,DELX,DELY,TITLE)
C -----------------------------------------------------------------------
C
C IDENTIFIER                 MEANING                                   TYPE
C
C IBUF:    ADDRESS OF BUFFER AREA FOR PLOT OUTPUT               INTEGER
C NLOC:    NUMBER OF LOCATIONS IN BUFFER AREA                   INTEGER
C LDEV:    LOGICAL DEVICE NUMBER FOR PLOT                       INTEGER
C NTOT:    NUMBER OF POINTS TO BE PLOTTED                       INTEGER
C NTICX:   NUMBER OF TIC MARKS ON ABSCISSA (> OR = 2)           INTEGER
C NTICY:   NUMBER OF TIC MARKS ON ORDINATE (> OR = 2)           INTEGER
C XMAX:    UPPER LIMIT OF ABSCISSA DOMAIN                       REAL
C YMAX:    UPPER LIMIT OF ORDINATE RANGE                        REAL
C XMIN:    LOWER LIMIT OF ABSCISSA DOMAIN                       REAL
C YMIN:    LOWER LIMIT OF ORDINATE RANGE                        REAL
C ITITLX:  ABSCISSA LABEL                                       FIELDATA ARRAY
C ITITLY:  ORDINATE LABEL                                       FIELDATA ARRAY
C LTITLX:  NUMBER OF CHARACTERS IN ITITLX                       INTEGER
C LTITLY:  NUMBER OF CHARACTERS IN ITITLY                       INTEGER
C XARRAY:  ABSCISSA POINTS IN TERMS OF XMIN - XMAX COORD"S   REAL ARRAY
C YARRAY:  ORDINATE POINTS IN TERMS OF YMIN - YMAX COORD"S   REAL ARRAY
C DELX:    INTERVALS OF ABSCISSA TIC MARK LABELING
C          IN TERMS OF XMIN - XMAX COORDINATES                   REAL
C DELY:    INTERVALS OF ORDINATE TIC MARK LABELING
C          IN TERMS OF YMIN - YMAX COORDINATES                   REAL
C TITLE:   LABEL FOR THE WHOLE RUN                              FIELDATA ARRAY
C
C -----------------------------------------------------------------------
      DIMENSION IBUF(NLOC),XARRAY(NTOT),YARRAY(NTOT),ITITLX(1),
     1  ITITLY(1),YDIT(100)
      DIMENSION TITLE(1)
      REAL LEFMAR,LABSEP
      COMMON  /BLK6/HEIGHT,J,INTEQ,ABSCIS,ORDINA,ICODE,TOPMAR,BOTMAR,
     1              LEFMAR,RYTMAR,FACT,MAXIS,MLINE,TICKLE,STARTL,SEPLAB,
     2              SYMBLH,LABSEP,ASTART,YDIT,ROTFAC
C -----------------------------------------------------------------------
C
C     FIXED BASIC PARAMETERS
C
C -----------------------------------------------------------------------
      DATA J/1/
      DATA HEIGHT/.105/
      DATA INTEQ/1/
      DATA ABSCIS/7.5/
      DATA ORDINA/4.5/
      DATA ICODE/ - 1/
      DATA TOPMAR/1.6/
      DATA BOTMAR/2.4/
```

```
      DATA LEFMAR/1.9/
      DATA RYTMAR/1.6/
      DATA FACT/1./
      DATA MAXIS/1/
      DATA MLINE/1/
C -----------------------------------------------------------------------
C
C     19 INITIAL COMPUTATION OF DERIVED PARAMETERS
C        AND INITIAL PLOTS CALL
C     20 SKIPS PRELIMINARIES FOR 2ND AND SUBSEQUENT CALLS
C
C -----------------------------------------------------------------------
      IF (J .GT. 1) GO TO 20
19    YDIT(1) = 3./19.
      TICKLE = HEIGHT/2.
      ROTFAC = - 11.0/14.0 * HEIGHT
      STARTL = 6 * HEIGHT + ROTFAC + TICKLE
      SEPLAB = STARTL + 1.5 * HEIGHT
      SYMBLH = 0.070
      LABSEP = 4. * HEIGHT
      ASTART = 2. * HEIGHT
      LEFMAR = LEFMAR + 0.5
      RYTMAR = RYTMAR - 0.5
      DO 1 I = 2,100
1     YDIT(I) = YDIT(I - 1) + (2 * MOD(I,2) + 1)/19.
      YDIT(100) = YDIT(100) + .5
      CALL PLOTS(IBUF,NLOC,LDEV,00)
      CALL FACTOR(1.)
      J = 2
      CALL SYMBOL (HEIGHT,36 * HEIGHT + 5.5,HEIGHT,TITLE,270.,70)
      CALL PLOT(1., 0.0, - 3)
3     DO 2 I = 1,100
2     CALL PLOT(0.,YDIT(I),3 - MOD(I,2))
      DO 33 I = 1,100
33    YDIT(I) = YDIT(I) - ABSCIS - RYTMAR
C -----------------------------------------------------------------------
C
C     RESET ORIGIN
C
C -----------------------------------------------------------------------
      XPAGE = BOTMAR + ORDINA
      GO TO 2019
20    XPAGE = BOTMAR + ORDINA + TOPMAR
2019  CALL WHERE(RXPAGE,RYPAGE,FACT)
      YPAGE = RYPAGE - LEFMAR
      CALL PLOT(XPAGE,YPAGE, - 3)
      CALL FACTOR(FACT)
C -----------------------------------------------------------------------
C
C     DRAW AXES AND LABELING MAXIS TIMES
C
C -----------------------------------------------------------------------
```

```
      DO 100 I = 1,MAXIS
100   CALL MYAXIS(NTICX,NTICY,ITITLX,ITITLY,XMAX,YMAX,XMIN,YMIN,
     1            LTITLX,LTITLY,DELX,DELY)
C -----------------------------------------------------------------
C
C     DRAW POINTS, OPTIONAL CENTERLINE,AND PAGE SCISSORLINE
C     MLINE TIMES
C
C -----------------------------------------------------------------
      DO 200 I = 1,MLINE
200   CALL MYLINE(XARRAY,YARRAY,XMAX,YMAX,XMIN,YMIN,NTOT,NTICY)
      RETURN
      END


      SUBROUTINE MYAXIS(NTICX,NTICY,ITITLX,ITITLY,XMAX,YMAX,XMIN,YMIN,
     1             LTITLX,LTITLY,DELX,DELY)
      COMMON  /BLK6/HEIGHT,J,INTEQ,ABSCIS,ORDINA,ICODE,TOPMAR,BOTMAR,
     1                LEFMAR,RYTMAR,FACT,MAXIS,MLINE,TICKLE,STARTL,SEPLAB,
     2                SYMBLH,LABSEP,ASTART,YDIT,ROTFAC
      REAL    LABSEP,LEFMAR
      DIMENSION ITITLX(1),ITITLY(1),YDIT(100)
      STARTL = 6 * HEIGHT + ROTFAC + TICKLE
      IMAX = IFIX((YMAX - YMIN)/DELY + 0.5)
      TICSEP = ORDINA/(IABS(NTICY) - 1)
      CALL DENDEC(YMAX,DELY,NDEC)
      K = 1
      N = (IABS(NTICY)/IMAX) - 1 + MOD(IABS(NTICY),2)
      IMAX1 = IMAX + 1
      DO 9 ILOOP = 1, IMAX1
      I = ILOOP - 1
      NNDEC = 0
      IF (K .NE. 1) GO TO 12
11    IF(2 * I.LT.IMAX)GO TO 12
      CALL AXLAB(0.,ITITLY,LTITLY)
      K = 2
12    FPN = YMAX - I * DELY
      IF (NDEC .LT. 0 .AND. ABS(FPN) .LT. 0.5) FPN = 0.0
      IF (NDEC .GT. 0 .AND. ABS(FPN) .LT. 5.0*10.0**(-NDEC-1)) FPN = 0.0
      TMID = 1.
      XPAGE =  - I * ORDINA/IMAX - .5 * HEIGHT
      IF(FPN)113,122,118
113   IF(NDEC - 2)115,114,112
114   YPAGE = STARTL
      GO TO 112
115   IF(NDEC - 1)117,116,112
116   YPAGE = STARTL - HEIGHT
      GO TO 112
117   IF(ABS(FPN) - 100.)119,118,118
119   IF(ABS(FPN) - 10.)120,121,121
120   YPAGE = STARTL - 3 * HEIGHT
      GO TO 112
```

```
121     YPAGE = STARTL - 2 * HEIGHT
        GO TO 112
122     YPAGE = STARTL - 4 * HEIGHT
        GO TO 112
118     IF(NDEC - 2)123,116,112
123     IF(NDEC - 1)125,124,112
124     IF(FPN - 10.)121,116,116
125     IF(FPN - 10.)122,120,126
126     IF(FPN - 100.)120,121,127
127     IF(FPN - 1000.)121,116,128
128     IF(FPN - 10000.)116,114,114
112     NNDEC = -1
        IF (FPN .NE. 0.0) NNDEC = NDEC
        CALL NUMBER(XPAGE,YPAGE,HEIGHT,FPN,270.,NNDEC)
        XPAGE =  - I * (ORDINA/IMAX)
        DO 10 JJ = 1,N
        YPAGE = TICKLE * TMID
        CALL PLOT(XPAGE,YPAGE,3)
        YPAGE = YPAGE * ( - 1 + I/IMAX * .5)
        CALL PLOT(XPAGE,YPAGE,2)
        IF(I/IMAX)110,110,9
110     YPAGE = 0
        CALL PLOT(XPAGE,YPAGE,3)
        XPAGE = XPAGE - TICSEP
        CALL PLOT(XPAGE, YPAGE,2)
        TMID = .5
10      CONTINUE
9       CONTINUE
        K = 1
        IMAX = IFIX((XMAX-XMIN)/DELX + 0.5)
        TICSEP = ABSCIS/(NTICX - 1)
        XPAGE =  - ASTART - ORDINA
        CALL DENDEC(XMAX,DELX,NDEC)
        IMAX1 = IMAX + 1
        DO 28 ILOOP = 1, IMAX1
        I = ILOOP - 1
        NNDEC = 0
        STARTL =  - I * ABSCIS/IMAX
        IF (K .GT. 1) GO TO 25
24      IF(2 * I.LT.IMAX)GO TO 25
        CALL AXLAB(270.,ITITLX,LTITLX)
        K = 2
        XPAGE =  - ASTART - ORDINA
25      FPN = XMIN + I * DELX
        IF (NDEC .LT. 0 .AND. ABS(FPN) .LT. 0.5) FPN = 0.0
        IF (NDEC .GT. 0 .AND. ABS(FPN) .LT. 5.0*10.0**(-NDEC-1)) FPN = 0.0
        IF(FPN)813,822,818
813     IF(NDEC - 2)815,814,23
814     YPAGE = STARTL + 16./7. * HEIGHT
        GO TO 23
```

```
815   IF(NDEC - 1)817,816,23
816   YPAGE = STARTL + 25./14. * HEIGHT
      GO TO 23
817   IF(ABS(FPN) - 100.)819,816,816
819   IF(ABS(FPN) - 10.)820,821,821
820   YPAGE = STARTL + 11./14. * HEIGHT
      GO TO 23
821   YPAGE = STARTL + 9./7. * HEIGHT
      GO TO 23
822   YPAGE = STARTL + 2./7. * HEIGHT
      GO TO 23
818   IF(NDEC - 2)823,816,23
823   IF(NDEC - 1)825,824,23
824   IF(FPN - 10.)821,816,816
825   IF(FPN - 10.)822,820,826
826   IF(FPN - 100.)820,821,827
827   IF(FPN - 1000.)821,816,828
828   IF(FPN - 10000.)816,814,814
23    NNDEC = -1
      IF (FPN .NE. 0.0) NNDEC = NDEC
28    CALL NUMBER(XPAGE,YPAGE,HEIGHT,FPN,270.,NNDEC)
      N = (NTICX/IMAX) - 1 + MOD(NTICX,2)
      IMAX1 = IMAX + 1
      DO 26 ILOOP = 1, IMAX1
      I = IMAX1 - ILOOP
      TMID = 1.
      YPAGE =  - I * ABSCIS/IMAX
      DO 27 JJ = 1,N
      XPAGE =  - ORDINA - TICKLE * TMID
      CALL PLOT(XPAGE,YPAGE,3)
      XPAGE = XPAGE + 2.0*TICKLE*TMID
      CALL PLOT(XPAGE,YPAGE,2)
      IF (I .EQ. 0) GO TO 26
111   XPAGE =  - ORDINA
      CALL PLOT(XPAGE,YPAGE,3)
      YPAGE = YPAGE + TICSEP
      CALL PLOT(XPAGE,YPAGE,2)
      TMID = .5
27    CONTINUE
26    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MYLINE(XARRAY,YARRAY,XMAX,YMAX,XMIN,YMIN,NTOT,NTICY)
      COMMON /BLK6/HEIGHT,J,INTEQ,ABSCIS,ORDINA,ICODE,TOPMAR,BOTMAR,
     1              LEFMAR,RYTMAR,FACT,MAXIS,MLINE,TICKLE,STARTL,SEPLAB,
     2              SYMBLH,LABSEP,ASTART,YDIT,ROTFAC
      REAL      LEFMAR,LABSEP
      DIMENSION  XARRAY(NTOT), YARRAY(NTOT), YDIT(100)
      ITOP = IFIX((ABSCIS + RYTMAR + 0.5)*9.0 + 0.5)
      IBOT = IFIX(RYTMAR*9.0 + 0.5)
      DO 17 I = 1,NTOT
      XPAGE = (YARRAY(I) - YMAX)/(YMAX - YMIN) * ORDINA
      YPAGE = (XMIN - XARRAY(I))/(XMAX - XMIN) * ABSCIS
17    CALL SYMBOL(XPAGE,YPAGE,SYMBLH,INTEQ,270.,ICODE)
      IF(NTICY.GE.0)GO TO 22
      XPAGE =  - ORDINA/2.
      YPAGE =  - ABSCIS
      CALL PLOT(XPAGE,YPAGE,3)
      DO 18 I = IBOT,ITOP
18    CALL PLOT(XPAGE,YDIT(I),3 - MOD(I,2))
22    XPAGE = TOPMAR
      YPAGE =  - ABSCIS - RYTMAR - .5
      CALL PLOT(XPAGE,YPAGE,3)
      DO 21 I = 1,100
21    CALL PLOT(XPAGE,YDIT(I),3 - MOD(I,2))
      RETURN
      END


      SUBROUTINE AXLAB(ANGLE,IBCD,NCHARX)
      COMMON /BLK6/HEIGHT,J,INTEQ,ABSCIS,ORDINA,ICODE,TOPMAR,BOTMAR,
     1              LEFMAR,RYTMAR,FACT,MAXIS,MLINE,TICKLE,STARTL,SEPLAB,
     2              SYMBLH,LABSEP,ASTART,YDIT,ROTFAC
      REAL    LEFMAR,LABSEP
      DIMENSION  IBCD(1), YDIT(100)
      K = 2
      NCHAR = NCHARX
      IF (ABS(ANGLE) .GT. 0.1) GO TO 30
      XPAGE = - ORDINA*0.5 - NCHAR*HEIGHT*0.5
      YPAGE = SEPLAB
      GO TO 31
30    XPAGE = - ORDINA - LABSEP
      YPAGE = - ABSCIS*0.5 + NCHAR*HEIGHT*0.5
31    CALL SYMBOL(XPAGE,YPAGE,HEIGHT,IBCD,ANGLE,NCHAR)
      RETURN
      END


      SUBROUTINE DENDEC(QMAX,DELQ,NDEC)
      IF(INT(ABS(QMAX)).GE.10)GO TO 5
      IF(AMOD(ABS(QMAX - DELQ),.1).GE..01)GO TO 7
      NDEC = 1
      RETURN
5     NDEC =  - 1
      RETURN
7     NDEC = 2
      RETURN
      END
```

```
      SUBROUTINE GROWTH(MAXP,TIMAX,PMAX,FREQ)
      DIMENSION TIMAX(1), PMAX(1), TIME(100), PEAK(100), ALPHA(100),
     1          T(100), F(100)
C
      DO 100 I = 1, MAXP
      TIME(I) = 0.0
      PEAK(I) = 0.0
      ALPHA(I) = 0.0
      T(I) = 0.0
      F(I) = 0.0
  100 CONTINUE
C
      K = 0
      J = 0
  110 K = K + 1
      IF (K .GT. MAXP) GO TO 120
      IF (PMAX(K) .LT. 0.0) GO TO 110
      J = J + 1
      TIME(J) = TIMAX(K)
      PEAK(J) = PMAX(K)
  140 IF (PMAX(K+1) .LT. PEAK(J)) GO TO 130
      K = K + 1
      TIME(J) = TIMAX(K)
      PEAK(J) = PMAX(K)
      GO TO 140
C
  130 IF (PMAX(K+1) .LE. 0.0) GO TO 110
      K = K + 1
      GO TO 140
  120 CONTINUE
C
      NCYCLE = J - 1
      DO 150 I = 1, NCYCLE
      T(I) = 0.5 * (TIME(I) + TIME(I+1))
      F(I) = 2.0 * FREQ / (TIME(I+1) - TIME(I))
      ALPHA(I) = ALOG(PEAK(I+1)/PEAK(I)) * F(I)
  150 CONTINUE
C
      WRITE (6,6001) NCYCLE
      LINE = 4
      DO 255 IST = 1, NCYCLE, 8
      ISTART = IST
      ISTOP = IST + 7
      IF (ISTOP .GT. NCYCLE) ISTOP = NCYCLE
      WRITE (6,6024) (ALPHA(I), I = ISTART, ISTOP)
      WRITE (6,6024) (F(I), I = ISTART, ISTOP)
      WRITE (6,6024) (T(I), I = ISTART, ISTOP)
      WRITE (6,6014)
      LINE = LINE + 4
      IF (LINE .LT. 52) GO TO 255
      LINE = 0
      WRITE (6,6013)
  255 CONTINUE
C
```

```
6001 FORMAT (1H1,4X,35HPRESSURE GROWTH RATE AND FREQUENCY.,
    1          /,5X,23HTOTAL NUMBER OF CYCLES:,I3///)
6013 FORMAT (1H1)
6014 FORMAT (1H )
6024 FORMAT (1H ,7X,8F13.6)
C
     RETURN
     END
```

3.3 PROGRAM MA1

Program MA1 calculates the coefficients of both the linear and nonlinear terms in the equations describing the behavior of the mode amplitudes (i.e., Equations (25)) to be solved using the Method of Averaging (MOA).

Program Description. This program is very similar to Program SOLID1 in its structure, subroutines, input and output. Hence it is unnecessary to describe them in detail; a description of MA1 is obtained by substituting "MA1" for "SOLID1" and "MA2" for "SOLID2" in Section 3.1.

Sample Case. Here, a sample case utilizing Program MA1 is given. All of the motor parameters and specifications are the same as described in Section 3.1. In the following pages, printed output of MA1 for this sample case is presented.

```
TEST CASE FØR MA1
      1.23     0.078    0
    5    1    0    1    1
       2.5    4000.0      0.68    3525.0    1071.0       0.1
    1    1 1L
    2    2 2L
    3    3 3L
    4    4 4L
    5    5 5L
```

TEST CASE FOR MA1

GAMMA = 1.23000   UE = .0780

QUASI-STEADY NOZZLE.

PARTICLE DIA (IN MICRONS) = 2.50   CM = .1000   FREQ (IN HERTZ) = 1071.0

CHAMBER TEMP (IN DEG K) = 3525.0   SP = .6800   RHOM (IN KG/CUBIC METER) = 4000.0

PARTICLE DRAG COEFFICIENT, K = 29.9186

NAME	J	L	EPS	ETA	YR	YI
1L	1	1	3.14159	.00828	.00683	0.00000
2L	2	2	6.28319	.00828	.00683	0.00000
3L	3	3	9.42478	.00828	.00683	0.00000
4L	4	4	12.56637	.00828	.00683	0.00000
5L	5	5	15.70796	.00828	.00683	0.00000

DECOUPLED COEFFICIENT OF B(P): C(I,J,P)

J \ P	1	2	3	4	5	6	7	8	9	10
1	-80.132388	-.000570	.133085	-.103311	-.113016	.155027	.107806	-.206771	-.105898	.258393
2	.000570	-80.132388	.103311	.133085	-.155027	-.113016	.206771	.107806	-.258393	-.105898
3	-.032928	-.051624	-50.523462	-.000448	.178861	-.155519	-.132860	.207223	.118936	-.258794
4	.051624	-.032928	.000448	-50.523462	.155519	.178861	-.207223	-.132860	.258794	.118936
5	.012518	.051787	-.079385	-.103580	-1.174986	-.000498	.226296	-.207421	-.154654	.258872
6	-.051787	.012518	.103580	-.079385	.000498	-1.174986	.207421	.226296	-.258872	-.154654
7	-.006968	-.051849	.033611	.103699	-.128183	-.155448	67.913152	-.000759	.273908	-.258774
8	.051849	-.006968	-.103699	.033611	.155448	-.128183	.000759	67.913152	.258774	.273908
9	.004833	.051871	-.020143	-.103711	.057562	.155440	-.178514	-.206929	156.741514	-.002091
10	-.051871	.004833	.103711	-.020143	-.155440	.057562	.206929	-.178514	.002091	156.741514

CECOUFLEC CCEFFICIENT OF THE CERIVATIVE OF B(P): C(2,J,P)

J \ P	1	2	3	4	5	6	7	8	9	10
1	3.274489	.001976	-.432544	-.002414	.367537	.003336	-.349332	-.004171	.341522	.005391
2	-.001976	3.274489	.002414	-.432544	-.003336	.367537	.004171	-.349332	-.005391	.341522
3	.087440	-.001297	3.274495	.001493	-.578157	-.001708	.432557	.002679	-.387984	-.004068
4	.001297	.087440	-.001493	3.274495	.001708	-.578157	-.002679	.432557	.004068	-.387984
5	-.022439	.000712	.233038	-.001405	3.274503	.001585	-.729714	-.001988	.504076	.003758
6	-.000712	-.022439	.001405	.233038	-.001585	3.274503	.001988	-.729714	-.003758	.504076
7	.004238	-.000439	-.087434	.000952	.384569	-.001780	3.274523	.002332	-.883266	-.003984
8	.000439	.004238	-.000952	-.087434	.001780	.384569	-.002332	3.274523	.003984	-.883266
9	.003563	.000247	.042857	-.000782	-.158913	.001665	.538056	-.003301	3.274583	.006367
10	-.000247	.003563	.000782	.042857	-.001665	-.158913	.003301	.538056	-.006367	3.274583

DECOUPLED COEFFICIENT OF G(P): C(3,J,P)

J \ P	1	2	3	4	5	6	7	8	9	10
1	2692.720690	.017047	-3.951641	-.021209	3.334118	.029961	-3.161177	-.037894	3.086992	.049488
2	-.017047	2692.720690	.021209	-3.951641	-.029961	3.334118	.037894	-3.161177	-.049488	3.086992
3	.587902	-.011627	2692.720732	.013493	-5.334866	-.015536	3.951757	.024754	-3.528337	-.037949
4	.011627	.987902	-.013493	2692.720732	.015536	-5.334866	-.024754	3.951757	.037949	-3.528337
5	-.370430	.006768	2.370992	-.013351	2692.720803	.015052	-6.774565	-.018880	4.631139	.035694
6	-.006768	-.370430	.013351	2.370992	-.015052	2692.720803	.018880	-6.774565	-.035694	4.631139
7	.197531	-.004859	-.587841	.009737	3.810445	-.017599	2692.721000	.022847	-8.233224	-.038536
8	.004859	.197531	-.009737	-.987841	.017599	3.810445	-.022847	2692.721000	.038536	-8.233224
9	-.123417	.004078	.564375	-.009159	-1.666838	.017541	5.268469	-.033082	2692.721576	.062211
10	-.004078	-.123417	.009159	.564375	-.017541	-1.666838	.033082	5.268469	-.062211	2692.721576

DECOUPLED COEFFICIENT OF THE REAL PART OF THE COMBUSTION TERM: E(J,P,1)

J \ P	1	2	3	4	5	6	7	8	9	10
1	-.094555	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	.000000
2	-.000000	-.094555	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000
3	-.000000	.000000	-.094555	.000000	.000000	-.000000	.000000	.000000	-.000000	-.000000
4	-.000000	-.000000	-.000000	-.094555	.000000	-.000000	-.000000	.000000	.000000	-.000000
5	.000000	-.000000	-.000000	.000000	-.094555	-.000000	-.000000	-.000000	.000000	.000000
6	.000000	.000000	-.000000	-.000000	.000000	-.094555	.000000	-.000000	-.000000	.000000
7	-.000000	.000000	.000000	-.000000	-.000000	.000000	-.094555	-.000000	-.000000	-.000000
8	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	-.094555	.000000	-.000000
9	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	-.094555	-.000000
10	.000000	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	-.094555

DECOUFLED COEFFICIENT OF THE IMAGINARY FART OF THE COMBUSTION TERM: E(J,P,2)

J \ P	1	2	3	4	5	6	7	8	9	10
1	.000000	.094555	-.000000	.000000	.000000	-.000000	-.000000	.000000	.000000	-.000000
2	-.094555	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	.000000
3	.000000	.000000	.000000	.094555	-.000000	.000000	.000000	-.000000	-.000000	.000000
4	-.000000	.000000	-.094555	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000
5	-.000000	-.000000	.000000	.000000	-.000000	.094555	-.000000	.000000	.000000	-.000000
6	.000000	-.000000	-.000000	.000000	-.094555	-.000000	-.000000	-.000000	.000000	.000000
7	.000000	.000000	-.000000	-.000000	.000000	.000000	-.000000	.094555	-.000000	.000000
8	-.000000	.000000	.000000	-.000000	-.000000	.000000	-.094555	-.000000	-.000000	-.000000
9	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	.000000	-.000000	.094555
10	.000000	-.000000	-.000000	.000000	.000000	-.000000	-.000000	.000000	-.094555	-.000000

DECOUPLED COEFFICIENT OF B(P) * DB(Q)/DT IN EQUATION FOR B(1)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	-.000380	-.038264	18.692389	-.010060	-.000762	.057837	.000460	-.032653	.000898	.023676
2	-.038313	-.008350	.019021	-.015937	-.143228	-.057781	.120355	.031676	-.113435	-.075595
3	15.550245	.015463	-.001496	-.060807	55.029566	-.056398	.000512	.189087	-.001525	-.110003
4	.011323	-.026345	-.060881	-.125516	.074478	.004360	-.337320	-.276405	.266250	.198513
5	-.000980	-.125284	49.792663	.062120	-.000777	-.087603	109.008728	-.125457	.000386	.383718
6	.016660	-.016518	-.027213	-.008390	-.087689	-.435345	.153947	.160530	-.592387	-.502355
7	.000992	.105982	.000503	-.304149	101.676899	.133201	-.002220	-.115789	180.634262	-.217844
8	.015631	-.016631	.133628	-.234061	-.088089	.151533	-.115904	-.762329	.256892	.256848
9	.000705	-.100007	-.001280	.239061	.000287	-.544346	171.207648	.227806	-.003835	-.144050
10	-.034375	-.044048	-.049518	.157441	.313583	-.444776	-.172209	.244867	-.144195	-1.182884

DECOUPLED COEFFICIENT OF E(P) * DB(Q)/DT IN EQUATION FOR B(2)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	.007927	.038397	.016962	-.019406	.056752	.143619	-.031252	-.120516	.075323	.113364
2	.038445	-.000374	.005046	18.692379	-.056690	-.000750	.030266	.000447	-.021028	.000908
3	.027254	-.012349	.123697	.061848	-.001438	-.075779	.273972	.338250	-.197601	-.265413
4	-.016063	15.550235	.061921	-.001477	.053410	55.029543	-.186055	.000536	.105395	-.001550
5	.015589	-.015441	.011110	.024180	.431082	.089816	-.154783	-.154885	.497986	.592364
6	.126235	-.000969	-.063756	49.792642	.089900	-.000746	.121296	109.008692	-.379535	.000427
7	.017031	-.018040	.231782	-.130492	-.146069	.083918	.754638	.117865	-.247347	-.257100
8	-.107287	.000981	.305811	.000524	-.134462	101.676865	.117979	-.002169	.212256	180.634202
9	.043785	.036982	-.156566	.045139	.440614	-.309488	-.235730	.166676	1.170784	.146361
10	.101555	.000712	-.239473	-.001300	.545078	.000324	-.228364	171.207591	.146504	-.003753

DECOUPLED COEFFICIENT OF E(P) * DB(Q)/DT IN EQUATION FOR B(3)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	-10.916997	.033350	-.000162	-.098338	28.562490	.008989	-.001239	.070901	-.000520	-.035760
2	.038888	.016267	-.032829	.098272	-.000423	-.034335	-.171820	-.071361	.134532	.101699
3	-.000098	-.048274	.001318	.076344	-.001268	-.175173	74.768228	-.019138	-.000655	.214548
4	-.102772	.102738	.076393	.016484	.018009	.175453	.036728	.078427	-.382412	-.324417
5	20.183188	.003238	-.001249	.002299	.000976	.096164	-.000127	-.295234	138.620144	-.057862
6	.045641	-.054746	-.172478	.172952	.096203	.242051	.087591	.159941	.086276	.122281
7	-.001373	-.141602	62.199038	.029814	.000034	.068713	.002762	.122104	-.000773	-.448090
8	.001719	-.001839	.023366	.074012	-.288287	.145525	.122159	.403520	.186282	.285275
9	-.080556	.114679	-.000438	-.330716	121.861329	.070537	-.000593	.163908	.004718	.149223
10	.033169	.065785	.127139	-.259826	-.007705	.113817	-.437266	.267659	.149294	.612561

DECOUPLED COEFFICIENT OF B(P) * DB(Q)/DT IN EQUATION FOR B(4)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	-.015839	-.038548	-.098849	.032959	.035739	-.000763	.069985	.172909	-.101190	-.134758
2	-.033047	-10.917000	.098786	-.000157	-.009077	28.562484	-.070439	-.001229	.034348	-.000530
3	-.103216	.103185	-.016061	-.077027	-.176976	-.016201	-.074840	-.040122	.321431	.383931
4	.048424	-.000093	-.077075	.001309	.177264	-.001262	.019083	74.768222	-.214423	-.000637
5	.055808	-.046023	-.174221	.174702	-.241076	-.097956	-.163132	-.085739	-.115674	-.090719
6	-.004461	20.183181	-.000371	-.001243	-.097994	.000971	.297368	-.000126	.059504	138.620134
7	.000726	-.000840	-.070972	-.023970	-.148356	.290578	-.401700	-.123312	-.290691	-.184487
8	.143196	-.001365	-.033233	62.199034	-.066839	.000035	-.123366	.002757	.450333	-.000770
9	-.065342	-.034715	.257226	-.126670	-.107945	.008832	-.272609	.439654	-.609643	-.150357
10	-.115968	-.000561	.332589	-.000426	-.074809	121.861322	-.162131	-.000591	-.150426	.004709

DECOUPLED COEFFICIENT OF B(P) * DB(Q)/DT IN EQUATION FOR B(5)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	.000058	.022851	-20.787178	.047571	-.000259	-.152392	38.432588	.023855	-.000394	.086286
2	.022853	-.038815	.054722	-.020997	-.031943	.152107	-.015854	-.048942	-.203893	-.175838
3	-23.929455	.052680	-.000677	-.131550	.000525	.139525	-.000022	-.254444	94.508429	.002351
4	.057982	-.020261	-.131603	.069136	.067756	-.140436	.061520	.107985	.015685	.084388
5	-.000050	-.074901	.000578	.079731	-.000795	-.114272	-.001039	.188516	-.001209	-.413072
6	-.159954	.159759	.144690	-.145641	-.114292	-.197285	.046194	-.020855	.172759	.245075
7	22.721353	-.002383	.000347	.020302	-.001077	.057733	-.002686	-.133647	-.001119	.258614
8	.078346	-.082037	-.242451	.074375	.190442	-.013183	-.133681	-.298529	.022789	-.071243
9	.000065	-.157415	72.512361	.015481	-.000848	.124473	-.001138	.035162	-.004602	-.157976
10	-.018527	-.114616	.059495	.082934	-.390422	.205264	.258637	-.063036	-.158021	-.435441

DECOUPLED COEFFICIENT OF B(P) * DB(Q)/DT IN EQUATION FOR B(6)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	.038203	-.023171	.021888	-.053978	-.152945	.032282	.050780	.013921	.174081	.205049
2	-.023173	.000059	-.047327	-20.787181	.152662	-.000256	-.023860	38.432585	-.086584	-.000388
3	.021244	-.057616	-.069898	.131403	.140897	-.068592	-.109866	-.058951	-.079950	-.019120
4	-.051880	-23.929458	.131455	-.000667	-.141814	.000521	.255513	-.000030	-.000394	94.508430
5	-.160433	.160241	.146041	-.146999	.196782	.115831	.021680	-.046042	-.248796	-.170220
6	.075117	-.000045	-.080766	.000573	.115849	-.000793	-.190941	-.001030	.412755	-.001225
7	.083231	-.079075	-.075770	.243957	.013898	-.192878	.297776	.134112	.072675	-.021395
8	.000485	22.721350	-.017743	.000340	-.057686	-.001069	.134144	-.002688	-.261510	-.001107
9	.113338	.018880	-.079470	-.058340	-.208320	.390446	.064322	-.261488	.434213	.158099
10	.159002	.000067	-.018495	72.512365	-.122163	-.000863	-.033861	-.001127	.158142	-.004601

DECOUPLED COEFFICIENT OF B(P) * DB(Q)/DT IN EQUATION FOR B(7)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	.000166	-.009574	.000548	.040252	-30.657002	.061386	-.000487	-.205078	48.301388	.038150
2	-.009572	.021319	.053239	-.040857	.069012	-.034513	-.031446	.204892	-.029912	.070164
3	.000592	.059202	-43.668233	.066983	.000212	-.204302	-.001054	.196217	-.000713	-.328708
4	.048432	-.049142	.078041	.033064	-.166372	.204378	.065390	.022251	.099176	.146582
5	-39.036405	.073697	.000212	-.183466	.000702	.154719	.000972	-.180517	-.000536	.259623
6	.073479	-.029776	-.217846	.217834	.154723	.208368	-.105132	-.043602	.017128	-.052137
7	-.000182	-.112984	-.001217	.096196	.000985	-.115876	.002873	.153690	.001032	-.218976
8	-.215486	.215518	.204971	.046488	-.186154	-.050838	.153710	.262869	-.094085	-.006328
9	23.162878	-.003835	-.000244	.024730	-.000584	.046553	.001019	-.104252	.004804	.171791
10	.113244	.087865	-.303436	.083235	.259673	-.030154	-.222593	-.012662	.171821	.359359

DECOUPLED COEFFICIENT OF B(P) * DB(Q)/DT IN EQUATION FOR B(8)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	-.021103	.009606	.039866	-.053786	.035857	-.068089	-.205999	.032252	-.067881	.027948
2	.009604	.000167	-.040508	.000547	-.060999	-30.657002	.205821	-.000490	-.037375	48.301392
3	.048022	-.048729	-.031140	-.076830	-.205555	.166246	-.021674	-.066177	-.148867	-.097688
4	-.059808	.000591	-.065809	-43.668238	.205639	.000216	-.198033	-.001044	.328222	-.000730
5	.031395	-.072824	-.219084	.219080	-.207929	-.155949	.043171	.104159	.053053	-.015999
6	-.072604	-39.036407	.183497	.000216	-.155953	.000702	.181945	.000962	-.260515	-.000515
7	-.216400	.216439	-.046010	-.206942	.050453	.187549	-.262446	-.153136	.005674	.091548
8	.113677	-.000182	-.097193	-.001209	.114958	.000975	-.153155	.002878	.220469	.001019
9	-.086608	-.113523	-.084758	.303317	.030876	-.260466	.012078	.223987	-.358705	-.170641
10	.002133	23.162883	-.023602	-.000261	-.045452	-.000564	.101761	.001007	-.170670	.004808

DECOUPLED COEFFICIENT OF B(P) * DB(Q)/DT IN EQUATION FOR B(9)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	-.000241	.005584	-.000095	-.016612	.000661	.057441	-40.526500	.074339	.000053	-.258098
2	.005501	-.014834	-.024643	.016615	.085898	-.058185	.082469	-.047753	-.031720	-.008279
3	-.000077	-.027080	-.000257	.102048	-63.406228	.080509	.000996	-.276383	-.000199	.251774
4	-.020415	.020420	.102062	-.140385	.094005	-.027366	-.202050	-.162448	.066079	.019930
5	.000725	.101311	-68.645271	.085470	-.001169	-.282774	-.000278	.220931	.000278	-.240206
6	.081233	-.082133	.097331	-.027489	-.282752	-.319990	.174211	.116741	-.102608	-.037075
7	-56.237651	.096549	.001086	-.244487	-.000246	.187134	-.003928	-.190268	-.000399	.221519
8	.085132	-.036096	-.306250	-.198969	.230663	.126401	-.190277	-.266944	.144153	.061326
9	.080596	-.163022	-.000133	.121714	.000191	-.129195	-.000349	.154237	-.005974	-.193571
10	-.271445	-.127229	.264117	.065748	-.250109	-.056771	.227532	.067813	-.193591	-.328497

CECOUFLEC CCEFFICIENT OF B(P) * CB(Q)/DT IN EQUATION FOR B(10)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	.014717	-.005458	-.016259	.024642	.056752	-.086372	.049547	-.082027	.006900	.031746
2	-.005455	-.000242	.016260	-.000092	-.057491	.000655	-.074983	-40.526489	.257888	.000037
3	-.020044	.020047	.138540	-.102494	.030200	-.093368	.160848	.200913	-.019225	-.063441
4	.027035	-.000073	-.102508	-.000263	-.081091	-63.408218	.276675	.000977	-.251281	-.000175
5	.080466	-.081362	.030536	-.097847	.318054	.282102	-.116170	-.171000	.036578	.098712
6	-.101799	.000719	-.084883	-68.645261	.282079	-.001183	-.219994	-.000260	.239389	.000255
7	.038433	-.085577	.197160	.306450	-.125830	-.229582	.266560	.187366	-.060907	-.139297
8	-.096236	-56.237641	.243349	.001067	-.183836	-.000227	.187373	-.003941	-.220534	-.000383
9	.126135	.271304	-.065175	-.263087	.056349	.248897	-.067431	-.226350	.328074	.189948
10	.162712	.000581	-.118892	-.000108	.125179	.000168	-.149319	-.000333	.189967	-.005983

FORTRAN Source Code.

```
      PROGRAM MA1(INPUT,OUTPUT,DATA,
     1            TAPE5=INPUT,TAPE6=OUTPUT,TAPE9=DATA)
C
C
C     **************** PROGRAM MA1 **********************************
C
C
C          THIS PROGRAM COMPUTES THE COEFFICIENTS WHICH APPEAR
C     IN THE DIFFERENTIAL EQUATIONS WHICH GOVERN THE MODE-AMPLITUDE
C     FUNCTIONS.  THESE COEFFICIENTS CAN BE WRITTEN INTO A FILE
C     FOR INPUT TO PROGRAM MA2.
C
C     THE FOLLOWING INPUTS ARE REQUIRED:
C
C     THE FIRST CARD GIVES THE TITLE OF THE CASE.
C
C     SECOND CARD: GAM, UE, NOZZLE
C         GAM IS THE SPECIFIC HEAT RATIO.
C         UE IS THE STEADY STATE MACH NUMBER AT THE NOZZLE ENTRANCE.
C         NOZZLE SPECIFIES THE TYPE OF NOZZLE USED:
C            NOZZLE = 0     QUASI-STEADY
C            NOZZLE = 1     CONVENTIONAL NOZZLE
C
C     THIRD CARD: NJMAX, NONLIN, NEGL, NOUT, NPRTKL
C         NJMAX IS THE NUMBER OF MODE-AMPLITUDE FUNCTIONS IN THE ASSUMED
C         SERIES SOLUTION.
C         THE COEFFICIENTS COMPUTED ARE DETERMINED BY NONLIN AS FOLLOWS:
C            NONLIN = 0   LINEAR COEFFICIENTS ONLY
C            NONLIN = 1   BOTH LINEAR AND NONLINEAR COEFFICIENTS.
C         COEFFICIENTS TO BE NEGLECTED ARE DETERMINED BY NEGL
C         AS FOLLOWS:
C            NEGL = 0   TERMS SMALLER THAN 0.00001 ARE NEGLECTED.
C            NEGL = 1   LINEAR TERMS SMALLER THAN SM1 AND NONLINEAR
C                       TERMS SMALLER THAN SM2 ARE NEGLECTED.
C         THE OUTPUT IS DETERMINED BY NOUT AS FOLLOWS:
C            NOUT = 0  PRINTED OUTPUT ONLY
C            NOUT = 1  WRITE INTO A FILE AND PRINT OUTPUT.
C            NOUT = 2  WRITE INTO A FILE ONLY.
C         NPRTKL DETERMINES WHETHER THE PARTICLES ARE PRESENT:
C            NPRTKL = 0   PARTICLES NOT PRESENT.
C            NPRTKL = 1   PARTICLES PRESENT.
C
C     NEXT CARD ( ONLY IF NPRTKL=1): DIA, RHOM, SP, TEMP, FREQ, CM
C         DIA IS THE PARTICLE DIAMETER, IN MICRONS.
C         RHOM IS THE DENSITY OF THE PARTICLE MATERIAL, IN KG/M**3.
C         SP IS RATIO OF SPECIFIC HEATS OF PARTICLE MATERIAL AND GAS.
C         TEMP IS THE CHAMBER TEMPERATURE, IN DEGREES KELVIN.
C         FREQ IS THE FREQUENCY OF OSCILLATION IN PURE GAS, IN HERTZ.
C         CM IS THE PARTICLE LOADING.
C
C     NEXT CARD (NECESSARY ONLY IF NEGL = 1): SM1, SM2
C         SM1 AND SM2 ARE AS DEFINED ABOVE.
```

```
C
C     NEXT NJMAX CARDS ( ONLY IF NOZZLE = 1): J, AMPL(J), PHASE(J)
C          AMPL(J) IS THE MAGNITUDE OF THE NOZZLE ADMITTANCE
C          FOR THE J TH MODE.
C          PHASE(J) IS THE PHASE OF THE NOZZLE ADMITTANCE
C          FOR THE J TH MODE.
C
C     NEXT NJMAX CARDS: J, L(J), NAME(J)
C          EACH MODE-AMPLITUDE IS ASSIGNED AN INTEGER J.
C          THE MODE IS SPECIFIED BY THE INDEX L(J).
C          L(J) IS THE AXIAL MODE NUMBER AND MUST NOT EXCEED NJMAX.
C          NAME(J) IS A FOUR-CHARACTER NAME FOR THE J TH MODE.
C
C     ****************************************************************
C
C
      DIMENSION     L(6), NAME(6), TITLE(7),
     1              AMPL(6), PHASE(6), V(2), C(3,
     2              12,12),C1(12,12),JC(12),
     3              E(12,12,2),D(12,12,12),
     4              KMAX(6), TSR(2,12), TSQ(12),TS(3,12)
      COMPLEX       CRSLT, CI, ZEJ, ZEP1, ZEP2, AX(4), AXINT(4,3),
     1             DCOEF, B(6), BC(6),
     2             YNOZ(6), CC(5,6,6),CNORM(6),
     3             CD1(6,6,6), CD2(6,6,6),
     4             CD3(6,6,6), CD4(6,6,6), CCOSH, CSINH
      COMMON      B
C
C     DATA INPUT.
C
      MAXMD = 6
      MAXMD2 = 12
      MAXMD4 = 24
      PI = 3.1415926536
      SM1 = 0.00001
      SM2 = 0.00001
      CI = (0.0,1.0)
C
C     INPUT PARAMETERS.
    4 READ (5,5000) TITLE
      IF (EOF(5)) 600, 1
    1 CONTINUE
      READ (5,5001) GAM, UE, NOZZLE
      IF (GAM) 600, 600, 8
    8 READ (5,5004) NJMAX, NONLIN, NEGL, NOUT, NPRTKL
      IF (NPRTKL .EQ. 1) READ (5,5006) DIA, RHOM, SP, TEMP, FREQ, CM
      IF (NEGL .EQ. 1) READ (5,5005) SM1, SM2
      GAMMA = GAM * (1.0 + SP * CM) / (1.0 + SP * GAM * CM)
      IF (NOZZLE .EQ. 1)  GO TO 5
```

```
C     COMPUTE ADMITTANCE FOR QUASI-STEADY NOZZLE.
      Y = (GAMMA - 1.0) * UE/(2.0 * GAMMA)
      DO 3 J = 1, NJMAX
      AMPL(J) = Y
      PHASE(J) = 0.0
    3 CONTINUE
      GO TO 7
    5 DO 6 I = 1, NJMAX
      READ (5,5003) J, AMPL(J), PHASE(J)
    6 CONTINUE
    7 DO 10 I = 1, NJMAX
      READ (5,5002) J, L(J), NAME(J)
   10 CONTINUE
C
      DO 12 J = 1, NJMAX
      THETA = PHASE(J) * PI/180.0
      YR = AMPL(J) * COS(THETA)
      YI = AMPL(J) * SIN(THETA)
      YNOZ(J) = CMPLX(YR,YI)
   12 CONTINUE
C
      NJMAX2 = NJMAX
      IF (NPRTKL .EQ. 1) NJMAX2 = 2 * NJMAX
      ZE = 1.0
      ZCOMB = 1.0
      CAX = GAMMA + 1.0
      RHOP = 0.0
      IF (NPRTKL .EQ. 0) GO TO 14
      VISC = 8.834 * 0.00001 * (TEMP/3485.)**0.66
      PARTKL = (9.0*VISC) / (RHOM * FREQ * DIA * DIA * 10.**(-12))
      UPBYU = 2.0 / (1.0 + SQRT(1.0 + 8.0*UE/PARTKL))
      RHOP = CM/UPBYU
   14 CONTINUE
C
C     ****************************************************************
C
C     CALCULATE AXIAL ACOUSTIC EIGENVALUES.
C
C
C     COMPUTE EIGENVALUES.
      DO 40 J = 1, NJMAX
      LL = L(J)
      SMN = 0.0
      YAMPL = AMPL(J)
      YPHASE = PHASE(J)
      CALL EIGVAL(LL,SMN,GAMMA,ZE,YAMPL,YPHASE,CRSLT)
      B(J) = CRSLT
      BC(J) = CONJG(CRSLT)
   40 CONTINUE
```

```
C
C     ****************************************************************
C
C     CALCULATE LINEAR COEFFICIENTS.
C
      DO 100 NJ = 1, NJMAX
      DO 100 NP = 1, NJMAX
C
C     ZERO COEFFICIENT ARRAYS.
      DO 105 KC = 1, 5
      CC(KC,NJ,NP) = (0.0,0.0)
  105 CONTINUE
      NPM = NP
      NJM = NJ
C
C     CALCULATE AXIAL INTEGRALS.
  127 DO 130 NOPT = 1, 4
      CALL AXIAL1(NOPT,NPM,NJM,UE,ZE,CRSLT)
      AX(NOPT) = CRSLT
  130 CONTINUE
C
C     EVALUATE FUNCTIONS AT NOZZLE END.
      ZEJ = CCOSH(CI * BC(NJM) * ZE)
      ZEP1 = CCOSH(CI * B(NPM) * ZE)
      ZEP2 = CI * B(NPM) * CSINH(CI*B(NPM)*ZE)
C
C     COEFFICIENT OF THE SECOND DERIVATIVE OF A(P).
      CC(1,NJ,NP) = AX(1)
C
C     COEFFICIENT OF A(P).
      CC(2,NJ,NP) = - AX(2) + ZEP2*ZEJ
C
C     COEFFICIENT OF THE FIRST DERIVATIVE OF A(P).
      CC(3,NJ,NP) = (CAX*AX(3) + 2.0*AX(4)
     1              + GAMMA*YNOZ(NP)*ZEP1*ZEJ)
      CC(5,NJ,NP) = - GAMMA * AX(3)
      IF (NPRTKL .EQ. 0) GO TO 100
      CC(2,NJ,NP) = CC(2,NJ,NP) - PARTKL **2 *RHOP * AX(1)
     1              - PARTKL * (GAMMA - 1.0) * CM * AX(4)
      CC(3,NJ,NP) = CC(3,NJ,NP) + PARTKL * RHOP * AX(1)
      CC(4,NJ,NP) = RHOP * PARTKL**3 * AX(1)
     1              + (GAMMA - 1.0) * PARTKL**2 * CM * AX(4)
C
  100 CONTINUE
C
C     NORMALIZE LINEAR COEFFICIENTS.
      DO 140 NJ = 1, NJMAX
      CNORM(NJ) = CC(1,NJ,NJ)
      DO 140 NP = 1, NJMAX
      DO 140 KC = 1, 5
      CC(KC,NJ,NP) = CC(KC,NJ,NP)/CNORM(NJ)
  140 CONTINUE
```

```
C
C     *****************************************************************
C
C     COMPUTE NONLINEAR COEFFICIENTS.
C
      IF (NONLIN .EQ. 0)  GO TO 402
      G1 = (GAMMA - 1.0) * 0.5
C
      DO 200 NJ = 1, NJMAX
      DCOEF = 0.5/CNORM(NJ)
      DO 200 NP = 1, NJMAX
      DO 200 NQ = 1, NJMAX
C
      CD1(NJ,NP,NQ) = (0.0,0.0)
      CD2(NJ,NP,NQ) = (0.0,0.0)
      CD3(NJ,NP,NQ) = (0.0,0.0)
      CD4(NJ,NP,NQ) = (0.0,0.0)
C
  244 DO 240 J = 2, 3
      DO 240 NC = 1, 4
      CALL AXIAL2(J,NC,NP,NQ,NJ,ZE,CRSLT)
      AXINT(NC,J) = CRSLT
  240 CONTINUE
C
      CD1(NJ,NP,NQ) = AXINT(1,2) + G1*AXINT(1,3)
      CD2(NJ,NP,NQ) = AXINT(2,2) + G1*AXINT(2,3)
      CD3(NJ,NP,NQ) = AXINT(3,2) + G1*AXINT(3,3)
      CD4(NJ,NP,NQ) = AXINT(4,2) + G1*AXINT(4,3)
C
      CD1(NJ,NP,NQ) = CD1(NJ,NP,NQ) * DCOEF * (1.0,-1.0)
      CD2(NJ,NP,NQ) = CD2(NJ,NP,NQ) * DCOEF * (1.0,1.0)
      CD3(NJ,NP,NQ) = CD3(NJ,NP,NQ) * DCOEF * (1.0,1.0)
      CD4(NJ,NP,NQ) = CD4(NJ,NP,NQ) * DCOEF * (1.0,-1.0)
  200 CONTINUE
C
C     *****************************************************************
C
C     CALCULATE COEFFICIENTS FOR EQUIVALENT REAL SYSTEM.
C
  402 DO 350 NJ = 1, NJMAX
      NEWJ = (2 * NJ) - 1
      NEWJ1 = NEWJ + 1
      DO 360 NP = 1,NJMAX
      NEWP = (2 * NP) - 1
      NEWP1 = NEWP + 1
C
C     COEFFICIENTS OF LINEAR TERMS.
      CCR = REAL(CC(1,NJ,NP))
      CCI = AIMAG(CC(1,NJ,NP))
```

```
      C1(NEWJ,NEWP) = CCR
      C1(NEWJ,NEWP1) = -CCI
      C1(NEWJ1,NEWP) = CCI
      C1(NEWJ1,NEWP1) = CCR
 1040 CONTINUE
      DO 360 KC = 1, 3
      CCR = REAL(CC(KC+1,NJ,NP))
      CCI = AIMAG(CC(KC+1,NJ,NP))
      C(KC,NEWJ,NEWP) = CCR
      C(KC,NEWJ,NEWP1) = -CCI
      C(KC,NEWJ1,NEWP) = CCI
      C(KC,NEWJ1,NEWP1) = CCR
  360 CONTINUE
C
C     COEFFICIENTS OF THE COMBUSTION TERM.
      DO 370 NP = 1, NJMAX
      NEWP = 2*NP - 1
      NEWP1 = NEWP + 1
      CCR = REAL(CC(5,NJ,NP))
      CCI = AIMAG(CC(5,NJ,NP))
      E(NEWJ,NEWP,1) = CCR
      E(NEWJ,NEWP,2) = - CCI
      E(NEWJ,NEWP1,1) = - CCI
      E(NEWJ,NEWP1,2) = - CCR
      E(NEWJ1,NEWP,1) = CCI
      E(NEWJ1,NEWP,2) = CCR
      E(NEWJ1,NEWP1,1) = CCR
      E(NEWJ1,NEWP1,2) = - CCI
C
C     COEFFICIENTS OF NONLINEAR TERMS.
      IF (NONLIN .EQ. 0) GO TO 350
      DO 370 NQ = 1, NJMAX
      NEWQ = (2 * NQ) - 1
      NEWQ1 = NEWQ + 1
      CD1R = REAL(CD1(NJ,NP,NQ))
      CD1I = AIMAG(CD1(NJ,NP,NQ))
      CD2R = REAL(CD2(NJ,NP,NQ))
      CD2I = AIMAG(CD2(NJ,NP,NQ))
      CD3R = REAL(CD3(NJ,NP,NQ))
      CD3I = AIMAG(CD3(NJ,NP,NQ))
      CD4R = REAL(CD4(NJ,NP,NQ))
      CD4I = AIMAG(CD4(NJ,NP,NQ))
      D(NEWJ,NEWP,NEWQ) = CD1R + CD2R + CD3R + CD4R
      D(NEWJ,NEWP,NEWQ1) = -CD1I + CD2I - CD3I + CD4I
      D(NEWJ,NEWP1,NEWQ) = -CD1I - CD2I + CD3I + CD4I
      D(NEWJ,NEWP1,NEWQ1) = -CD1R + CD2R + CD3R - CD4R
      D(NEWJ1,NEWP,NEWQ) = CD1I + CD2I + CD3I + CD4I
      D(NEWJ1,NEWP,NEWQ1) = CD1R - CD2R + CD3R - CD4R
      D(NEWJ1,NEWP1,NEWQ) = CD1R + CD2R - CD3R - CD4R
      D(NEWJ1,NEWP1,NEWQ1) = -CD1I + CD2I + CD3I - CD4I
  370 CONTINUE
  350 CONTINUE
```

```
C
C     ****************************************************************
C
C     COMPUTE COEFFICIENTS FOR THE EQUATIONS WHICH ARE DECOUPLED
C     IN THE SECOND DERIVATIVES.
C
      DO 405 KC = 1, 6
      KMAX(KC) = 0
  405 CONTINUE
C
C     CALCULATE INVERSE OF THE MATRIX C1(I,J).
      JMAX = NJMAX
      NJMAX = 2 * NJMAX
C
C
      V(1) = 1
      CALL GJR(C1,MAXMD2,MAXMD2,NJMAX,0,JC,V)
C
C     USE INVERSE TO CALCULATE DECOUPLED COEFFICIENTS.
C
C
C     LINEAR COEFFICIENTS.
      DO 430 NP = 1, NJMAX
      DO 420 NJ = 1, NJMAX
      DO 420 KC = 1, 3
      TS(KC,NJ) = 0.0
      DO 420 K = 1, NJMAX
      TS(KC,NJ) = TS(KC,NJ) + C1(NJ,K) * C(KC,K,NP)
  420 CONTINUE
      DO 430 NJ = 1, NJMAX
      DO 430 KC = 1, 3
      C(KC,NJ,NP) = TS(KC,NJ)
      ABSVAL = ABS(C(KC,NJ,NP))
      IF (ABSVAL .GE. SM1)  KMAX(KC) = KMAX(KC) + 1
  430 CONTINUE
C
C     COEFFICIENTS OF THE COMBUSTION RESPONSE TERM.
      DO 720 NP = 1, NJMAX
      DO 725 NJ = 1, NJMAX
      TSR(1,NJ) = 0.0
      TSR(2,NJ) = 0.0
      DO 725 K = 1, NJMAX
      TSR(1,NJ) = TSR(1,NJ) + C1(NJ,K) * E(K,NP,1)
      TSR(2,NJ) = TSR(2,NJ) + C1(NJ,K) * E(K,NP,2)
  725 CONTINUE
      DO 730 NJ = 1, NJMAX
      E(NJ,NP,1) = TSR(1,NJ)
      ABSVAL = ABS(E(NJ,NP,1))
      IF (ABSVAL .GE. SM1) KMAX(4) = KMAX(4) + 1
      E(NJ,NP,2) = TSR(2,NJ)
      ABSVAL = ABS(E(NJ,NP,2))
      IF(ABSVAL .GT. SM1) KMAX(5) = KMAX(5) + 1
  730 CONTINUE
  720 CONTINUE
```

```
C
C     NONLINEAR COEFFICIENTS.
      IF (NONLIN .EQ. 0) GO TO 410
      DO 735 NP = 1, NJMAX
      DO 735 NQ = 1, NJMAX
      DO 440 NJ = 1, NJMAX
      TSQ(NJ) = 0.0
      DO 440 K = 1, NJMAX
      TSQ(NJ) = TSQ(NJ) + C1(NJ,K) * D(K,NP,NQ)
  440 CONTINUE
      DO 445 NJ = 1, NJMAX
      D(NJ,NP,NQ) = TSQ(NJ)
      ABSVAL = ABS(D(NJ,NP,NQ))
      IF (ABSVAL .GT. SM2) KMAX(6) = KMAX(6) + 1
  445 CONTINUE
  735 CONTINUE
C
  410 CONTINUE
C
C     ******************************************************************
C     OUTPUT.
C
      IF (NOUT .EQ. 2) GO TO 455
      WRITE (6,6001) TITLE
      WRITE (6,6002)  GAM, UE
      IF (NOZZLE .EQ. 0)  WRITE (6,6012)
      IF (NPRTKL .EQ. 0) WRITE (6,6022)
      IF (NPRTKL .EQ. 1) WRITE (6,6021) DIA, CM, FREQ,
     1     TEMP, SP, RHOM, PARTKL
      WRITE (6,6004)
      DO 310 J = 1, JMAX
      WRITE (6,6003) NAME(J), J, L(J), B(J), YNOZ(J)
  310 CONTINUE
      IF (NONLIN .EQ. 0)  WRITE (6,6013)
C
C     OUTPUT OF LINEAR COEFFICIENTS.
      DO 320 KC = 1, 3
      NJS = 0
      NJF = 0
      KOUNTJ = 1
  756 NJS = NJF + 1
      NJF = 10 * KOUNTJ
      IF (NJF .GT. NJMAX) NJF = NJMAX
      NPS = 0
      NPF = 0
      KOUNTP = 1
  754 NPS = NPF + 1
      NPF = 10 * KOUNTP
      IF (NPF .GT. NJMAX) NPF = NJMAX
      IF (KC .EQ. 1)  WRITE (6,6005)
      IF (KC .EQ. 2)  WRITE (6,6006)
      IF (KC .EQ. 3)  WRITE (6,6007)
```

```
      WRITE (6,6008) (NP, NP = NPS, NPF)
      WRITE (6,6014)
      DO 750 NJ = NJS, NJF
      WRITE (6,6009) NJ, (C(KC,NJ,NP), NP = NPS, NPF)
  750 CONTINUE
      IF (NPF .EQ. NJMAX) GO TO 752
      KOUNTP = KOUNTP + 1
      GO TO 754
  752 IF (NJF .EQ. NJMAX) GO TO 756
      KOUNTJ = KOUNTJ + 1
      GO TO 758
  756 CONTINUE
  320 CONTINUE
C
C     OUTPUT OF THE COMBUSTION RESPONSE TERM.
      DO 770 KC = 1, 2
      NJS = 0
      NJF = 0
      KOUNTJ = 1
  760 NJS = NJF + 1
      NJF = 10 * KOUNTJ
      IF (NJF .GT. NJMAX) NJF = NJMAX
      NPS = 0
      NPF = 0
      KOUNTP = 1
  762 NPS = NPF + 1
      NPF = 10 * KOUNTP
      IF (NPF .GT. NJMAX) NPF = NJMAX
      IF (KC .EQ. 1) WRITE (6,6019)
      IF (KC .EQ. 2) WRITE (6,6020)
      WRITE (6,6008) (NP, NP = NPS, NPF)
      WRITE (6,6014)
      DO 764 NJ = NJS, NJF
      WRITE (6,6009) NJ, (E(NJ,NP,KC), NP = NPS, NPF)
  764 CONTINUE
      IF (NPF .EQ. NJMAX) GO TO 766
      KOUNTP = KOUNTP + 1
      GO TO 762
  766 IF (NJF .EQ. NJMAX) GO TO 768
      KOUNTJ = KOUNTJ + 1
      GO TO 760
  768 CONTINUE
  770 CONTINUE
C
C     OUTPUT OF NONLINEAR COEFFICIENTS.
      IF (NONLIN .EQ. 0)  GO TO 452
      DO 400 NJ = 1, NJMAX
      NPS = 0
      NPF = 0
      KOUNTP = 1
  780 NPS = NPF + 1
      NPF = 10 * KOUNTP
      IF (NPF .GT. NJMAX) NPF = NJMAX
```

```
      NQS = 0
      NQF = 0
      KOUNTQ = 1
  776 NQS = NQF + 1
      NQF = 10 * KOUNTQ
      IF (NQF .GT. NJMAX) NQF = NJMAX
      WRITE (6,6010) NJ
      WRITE (6,6011) (NQ, NQ = NQS, NQF)
      WRITE (6,6015)
      DO 772 NP = NPS, NPF
      WRITE (6,6009) NP, (D(NJ,NP,NQ), NQ = NQS, NQF)
  772 CONTINUE
      IF (NQF .EQ. NJMAX) GO TO 774
      KOUNTQ = KOUNTQ + 1
      GO TO 776
  774 IF (NPF .EQ. NJMAX) GO TO 778
      KOUNTP = KOUNTP + 1
      GO TO 780
  778 CONTINUE
  400 CONTINUE
  452 IF (NOUT .EQ. 0)  GO TO 4
C
C     WRITE COEFFICIENTS ON FILE.
C
  455 WRITE (9,7001) GAMMA, UE, ZE, NJMAX, NPRTKL
      IF (NPRTKL .EQ. 1) WRITE (9,7007) DIA, RHOM, SP,
     1      TEMP, FREQ, PARTKL, CM
C
      DO 450 J = 1, JMAX
      WRITE (9,7002)  J, L(J), NAME(J)
  450 CONTINUE
C
      DO 457 J = 1, JMAX
      WRITE (9,7006) J, YNOZ(J), B(J)
  457 CONTINUE
C
      DO 460 KC = 1, 3
      WRITE (9,7003) KMAX(KC)
      DO 460 NJ = 1, NJMAX
      DO 460 NP = 1, NJMAX
      ABSVAL = ABS(C(KC,NJ,NP))
      IF (ABSVAL .GE. SM1)  WRITE (9,7004)  NJ, NP, C(KC,NJ,NP)
  460 CONTINUE
C
      DO 820 KC = 4, 5
      WRITE (9,7003) KMAX(KC)
      KCMIN3 = KC - 3
      DO 820 NJ = 1, NJMAX
      DO 820 NP = 1, NJMAX
      ABSVAL = ABS(E(NJ,NP,KCMIN3))
      IF (ABSVAL .GT. SM1) WRITE (9,7004) NJ, NP, E(NJ,NP,KCMIN3)
  820 CONTINUE
      WRITE (9,7003) KMAX(6)
      IF (NONLIN .EQ. 0)  GO TO 4
      DO 470 NJ = 1, NJMAX
      DO 470 NP = 1, NJMAX
      DO 470 NQ = 1, NJMAX
```

```
      ABSVAL = ABS(D(NJ,NP,NQ))
      IF (ABSVAL .GE. SM2)  WRITE (9,7005) NJ, NP, NQ, D(NJ,NP,NQ)
  470 CONTINUE
      GO TO 4
C
  600 CONTINUE
C
C     ******************************************************* *************
C
C
C     FORMAT SPECIFICATIONS.
 5000 FORMAT (7A10)
 5001 FORMAT (2F10.0,I5)
 5002 FORMAT (2I5, 1X, A4)
 5003 FORMAT (I5, 2F10.0)
 5004 FORMAT (6I5)
 5005 FORMAT (2F10.0)
 5006 FORMAT (6F10.0)
 6001 FORMAT (1H1, 1X, 7A10//)
 6002 FORMAT (2X, 8HGAMMA = ,F7.5, 5X, 4HUE =,F6.4,//)
 6003 FORMAT (2X, A4, 2I5, 4F10.5/)
 6004 FORMAT (2X////2X, 14HNAME     J    L, 6X, 3HEPS, 7X, 3HETA,
     1        8X, 2HYR, 7X, 2HYI//)
 6005 FORMAT (1H1, 45H  DECOUPLED COEFFICIENT OF B(P):      C(1,J,P)///)
 6006 FORMAT (1H1, 44H  DECOUPLED COEFFICIENT OF THE DERIVATIVE OF,
     1        6H B(P):, 5X, 8HC(2,J,P)///)
 6007 FORMAT (1H1, 42H  DECOUPLED COEFFICIENT OF G(P):    C(3,J,P)///)
 6008 FORMAT (7X, 1HP,I8,9I12)
 6009 FORMAT (2X//2X, I3, 3X, 10F12.6)
 6010 FORMAT (1H1, 42H  DECOUPLED COEFFICIENT OF B(P) * DB(Q)/DT,
     1        19H IN EQUATION FOR B(,I2, 1H)///)
 6011 FORMAT (7X, 1HQ,I8,9I12)
 6012 FORMAT (2X, 20HQUASI-STEADY NOZZLE./)
 6013 FORMAT (2X//2X, 24HLINEAR COEFFICIENTS ONLY)
 6014 FORMAT (4X, 1HJ)
 6015 FORMAT (4X, 1HP)
 6019 FORMAT (1H1, 40H  DECOUPLED COEFFICIENT OF THE REAL PART,
     1        24H OF THE COMBUSTION TERM:, 5X, 8HE(J,P,1)///)
 6020 FORMAT (1H1, 45H  DECOUPLED COEFFICIENT OF THE IMAGINARY PART,
     1        24H OF THE COMBUSTION TERM:, 5X, 8HE(J,P,2)///)
 6021 FORMAT (///, 10X, 27HPARTICLE DIA (IN MICRONS) = ,F5.2, 10X,
     1        4HCM =,F6.4, 10X, 18HFREQ (IN HERTZ) = ,F6.1, //,
     2        10X, 26HCHAMBER TEMP (IN DEG K) = ,F6.1, 10X, 4HSP =,
     3        F6.4, 10X, 27HRHOM (IN KG/CUBIC METER) = ,F6.1, //, 10X,
     4        30HPARTICLE DRAG COEFFICIENT, K =,F8.4, ////)
 6022 FORMAT (2X, 26HPARTICLES ARE NOT PRESENT.//)
 7001 FORMAT (3F10.5, 3I5)
 7002 FORMAT (2I5, 1X, A4)
 7003 FORMAT (I5)
 7004 FORMAT (2I5, F15.8)
 7005 FORMAT (3I5, F15.8)
 7006 FORMAT (I5, 4F12.8)
 7007 FORMAT (7F15.8)
      END
```

3.4 PROGRAM MA2

Program MA2 carries out a numerical integration of the mode-amplitude equations resulting from the application of the Galerkin method in combination with the method of averaging (i.e., Equations (39)).

Program Description. Just as Program MA1 is similar to Program SOLID1, Program MA2 is similar to Program SOLID2 in its structure, subroutines, input and output. Hence one is referred to Section 3.2 where a detailed description of Program SOLID2 is given.

Sample Case. In the following example, the same case considered in Section 3.2 is treated using Program MA2. The printed and plotted output of this case is presented in the following pages.

```
    0    0
TEST CASE FØR MA2
     0.025       0.0      10.0    1071.0       0.0
     5.996      0.58     0.575       4.2
    1    1    3    0    0
      0.15      0.05  -31
    1    1    1    1    1
      0.04      0.01  -41
    1 -.0266818       0.0
```

```
UE = .0780

NUMBER OF MODES = 5

GAMMA = 1.23

GAMMABAR = 1.212250


PARTICLE DIA (IN MICRONS) =  2.5      CM = .10      FREQ (IN HERTZ) = 1071.0

CHAMBER TEMP (IN DEG K) = 3525.0      SP = .68      RHOM (IN KG/CUBIC METER) = 4000.0

PARTICLE DRAG CONSTANT, K = 29.9186
```

NAME	J	L
1L	1	1
2L	2	2
3L	3	3
4L	4	4
5L	5	5

J	YR	YI	EPS	ETA
1	.00683	0.00000	3.14159	.00828
2	.00683	0.00000	6.28319	.00828
3	.00683	0.00000	9.42478	.00828
4	.00683	0.00000	12.56637	.00828
5	.00683	0.00000	15.70796	.00828

COEFFICIENTS FOR COMFUTATION OF WALL FRESSURE WAVEFORMS

COEFFICIENTS IN SERIES FOR:

J	Z	TIME CERIVATIVE	AXIAL DERIVATIVE
1	0.000	1.0000000	0.0000000
2	0.000	0.0000000	0.0000000
3	0.000	1.0000000	0.0000000
4	0.000	0.0000000	0.0000000
5	0.000	1.0000000	0.0000000
6	0.000	0.0000000	0.0000000
7	0.000	1.0000000	0.0000000
8	0.000	0.0000000	0.0000000
9	0.000	1.0000000	0.0000000
10	0.000	0.0000000	0.0000000
1	1.000	-1.0000343	-.0000685
2	1.000	.0000000	-.0260059
3	1.000	1.0000343	.0000685
4	1.000	.0000000	.0520119
5	1.000	-1.0000343	-.0000685
6	1.000	.0000000	-.0780178
7	1.000	1.0000343	.0000686
8	1.000	-.0000000	.1040237
9	1.000	-1.0000343	-.0000685
10	1.000	-.0000000	-.1300296
1	.500	.0000000	-3.1416196
2	.500	.0041389	.0082779
3	.500	-1.0000086	-.0000343
4	.500	-.0000000	-.0260057
5	.500	-.0000000	9.4248587
6	.500	-.0041389	-.0082779
7	.500	1.0000086	.0000343
8	.500	-.0000000	.0520114
9	.500	-.0000000	-15.7080978
10	.500	.0041389	.0082779

COMBUSTION PARAMETERS: A = 5.996   B = .580   EN = .575   OMEGA = 4.200

J	RESR	RESI
1	4.1401	.0926
2	.9605	-1.7016
3	.5013	-1.0872
4	.3777	-.8191
5	.3194	-.6694

LINEAR COMBUSTION RESFONSE.

LINEAR PARTICLE DAMFING.

```
INITIAL CONDITIONS ARE OF THE FORM:

L(I,J) =  AC(J)*COS(FREQ*T) + AS(J)*SIN(FREQ*T)

     J       FREQUENCY            AC(J)            AS(J)

     1      2.97369626       0.00000000       -.02668180
     2      2.97369626        .02523957        .00007032

THIS RUN PROCUCES PLOTTED OUTPUT.
```

MOTOR PARAMETERS: GAMMA = 1.21 EXIT MACH NUMBER = .07800

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
0	0.00000	.10957	-.10188	-.00002	.00021	-.00804
1	.02500	.10962	-.10201	-.00029	.00650	-.00180
2	.05000	.10897	-.10163	-.00055	.01278	.00448
3	.07500	.10763	-.10074	-.00080	.01899	.01074
4	.10000	.10560	-.09935	-.00104	.02512	.01696
5	.12500	.10292	-.09745	-.00128	.03112	.02310
6	.15000	.09960	-.09504	-.00153	.03696	.02913
7	.17500	.09569	-.09212	-.00178	.04261	.03500
8	.20000	.09122	-.08869	-.00204	.04803	.04070
9	.22500	.08624	-.08476	-.00232	.05318	.04617
10	.25000	.08078	-.08032	-.00262	.05805	.05140
11	.27500	.07489	-.07540	-.00296	.06260	.05635
12	.30000	.06862	-.06999	-.00333	.06681	.06099
13	.32500	.06202	-.06410	-.00373	.07064	.06529
14	.35000	.05514	-.05777	-.00417	.07407	.06922
15	.37500	.04803	-.05100	-.00465	.07709	.07277
16	.40000	.04072	-.04382	-.00516	.07968	.07591
17	.42500	.03327	-.03625	-.00570	.08182	.07863
18	.45000	.02572	-.02834	-.00627	.08351	.08090
19	.47500	.01811	-.02013	-.00685	.08472	.08273
20	.50000	.01049	-.01165	-.00745	.08546	.08408
21	.52500	.00287	-.00296	-.00804	.08573	.08497
22	.55000	-.00469	.00588	-.00861	.08552	.08539
23	.57500	-.01217	.01481	-.00915	.08484	.08533
24	.60000	-.01953	.02376	-.00965	.08369	.08480
25	.62500	-.02675	.03267	-.01009	.08207	.08381
26	.65000	-.03380	.04145	-.01046	.08000	.08234
27	.67500	-.04065	.05003	-.01074	.07749	.08043
28	.70000	-.04729	.05833	-.01092	.07454	.07807
29	.72500	-.05368	.06623	-.01099	.07118	.07527
30	.75000	-.05980	.07382	-.01093	.06741	.07205
31	.77500	-.06565	.08085	-.01074	.06325	.06843
32	.80000	-.07119	.08734	-.01040	.05873	.06441
33	.82500	-.07641	.09321	-.00992	.05385	.06002
34	.85000	-.08128	.09844	-.00929	.04865	.05527
35	.87500	-.08580	.10297	-.00852	.04315	.05019
36	.90000	-.08995	.10678	-.00760	.03737	.04480
37	.92500	-.09370	.10986	-.00656	.03134	.03912
38	.95000	-.09704	.11219	-.00539	.02509	.03318
39	.97500	-.09996	.11378	-.00412	.01867	.02702
40	1.00000	-.10243	.11462	-.00277	.01209	.02067
41	1.02500	-.10443	.11475	-.00136	.00541	.01416
42	1.05000	-.10596	.11417	.00007	-.00133	.00753
43	1.07500	-.10699	.11292	.00151	-.00809	.00082

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
44	1.10000	-.10749	.11102	.00292	-.01482	-.00592
45	1.12500	-.10747	.10851	.00426	-.02148	-.01264
46	1.15000	-.10689	.10542	.00551	-.02801	-.01930
47	1.17500	-.10573	.10179	.00663	-.03438	-.02586
48	1.20000	-.10398	.09767	.00760	-.04053	-.03226
49	1.22500	-.10162	.09309	.00839	-.04643	-.03847
50	1.25000	-.09862	.08808	.00898	-.05204	-.04443
51	1.27500	-.09498	.08271	.00935	-.05732	-.05011
52	1.30000	-.09068	.07699	.00951	-.06224	-.05547
53	1.32500	-.08570	.07097	.00943	-.06678	-.06049
54	1.35000	-.08004	.06469	.00913	-.07091	-.06513
55	1.37500	-.07369	.05818	.00861	-.07462	-.06938
56	1.40000	-.06666	.05148	.00789	-.07791	-.07322
57	1.42500	-.05898	.04462	.00698	-.08075	-.07662
58	1.45000	-.05065	.03762	.00590	-.08315	-.07960
59	1.47500	-.04174	.03054	.00468	-.08510	-.08213
60	1.50000	-.03228	.02339	.00334	-.08660	-.08421
61	1.52500	-.02235	.01617	.00191	-.08765	-.08585
62	1.55000	-.01204	.00896	.00042	-.08826	-.08705
63	1.57500	-.00145	.00176	-.00110	-.08842	-.08780
64	1.60000	.00932	-.00541	-.00263	-.08815	-.08810
65	1.62500	.02014	-.01251	-.00414	-.08743	-.08797
66	1.65000	.03089	-.01953	-.00560	-.08628	-.08740
67	1.67500	.04142	-.02643	-.00698	-.08470	-.08639
68	1.70000	.05163	-.03320	-.00825	-.08269	-.08495
69	1.72500	.06138	-.03983	-.00940	-.08025	-.08309
70	1.75000	.07056	-.04628	-.01039	-.07739	-.08080
71	1.77500	.07908	-.05254	-.01119	-.07411	-.07809
72	1.80000	.08687	-.05860	-.01178	-.07041	-.07495
73	1.82500	.09386	-.06443	-.01214	-.06630	-.07139
74	1.85000	.10002	-.07003	-.01225	-.06176	-.06742
75	1.87500	.10532	-.07537	-.01209	-.05682	-.06303
76	1.90000	.10977	-.08045	-.01164	-.05148	-.05823
77	1.92500	.11338	-.08523	-.01092	-.04574	-.05302
78	1.95000	.11613	-.08970	-.00993	-.03964	-.04743
79	1.97500	.11809	-.09383	-.00867	-.03319	-.04145
80	2.00000	.11929	-.09762	-.00718	-.02644	-.03513
81	2.02500	.11975	-.10102	-.00549	-.01942	-.02849
82	2.05000	.11951	-.10403	-.00365	-.01218	-.02157
83	2.07500	.11861	-.10662	-.00172	-.00480	-.01443
84	2.10000	.11707	-.10876	.00026	.00266	-.00712
85	2.12500	.11494	-.11045	.00221	.01014	.00030
86	2.15000	.11224	-.11164	.00408	.01754	.00774
87	2.17500	.10902	-.11233	.00579	.02481	.01513
88	2.20000	.10530	-.11249	.00730	.03186	.02241
89	2.22500	.10114	-.11208	.00854	.03863	.02950
90	2.25000	.09656	-.11107	.00949	.04506	.03633
91	2.27500	.09160	-.10943	.01010	.05111	.04284

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
92	2.30000	.08631	-.10710	.01037	.05675	.04899
93	2.32500	.08073	-.10404	.01027	.06195	.05474
94	2.35000	.07488	-.10018	.00983	.06670	.06006
95	2.37500	.06881	-.09548	.00906	.07099	.06494
96	2.40000	.06253	-.08988	.00798	.07484	.06938
97	2.42500	.05607	-.08334	.00663	.07824	.07336
98	2.45000	.04946	-.07582	.00505	.08121	.07690
99	2.47500	.04272	-.06732	.00329	.08376	.08001
100	2.50000	.03585	-.05786	.00137	.08589	.08270
101	2.52500	.02889	-.04748	-.00065	.08762	.08496
102	2.55000	.02185	-.03627	-.00274	.08893	.08681
103	2.57500	.01477	-.02435	-.00486	.08984	.08826
104	2.60000	.00766	-.01188	-.00699	.09034	.08929
105	2.62500	.00056	.00096	-.00911	.09044	.08993
106	2.65000	-.00650	.01396	-.01118	.09014	.09016
107	2.67500	-.01349	.02690	-.01320	.08943	.08998
108	2.70000	-.02039	.03955	-.01514	.08833	.08941
109	2.72500	-.02716	.05169	-.01697	.08683	.08844
110	2.75000	-.03380	.06313	-.01867	.08495	.08708
111	2.77500	-.04027	.07371	-.02020	.08268	.08533
112	2.80000	-.04659	.08330	-.02152	.08001	.08318
113	2.82500	-.05273	.09182	-.02258	.07693	.08064
114	2.85000	-.05870	.09923	-.02333	.07344	.07770
115	2.87500	-.06450	.10555	-.02372	.06950	.07434
116	2.90000	-.07010	.11080	-.02368	.06510	.07055
117	2.92500	-.07551	.11504	-.02318	.06021	.06629
118	2.95000	-.08071	.11836	-.02219	.05481	.06155
119	2.97500	-.08567	.12082	-.02067	.04888	.05630
120	3.00000	-.09036	.12252	-.01864	.04243	.05054
121	3.02500	-.09475	.12351	-.01612	.03547	.04426
122	3.05000	-.09881	.12384	-.01315	.02806	.03747
123	3.07500	-.10250	.12355	-.00981	.02024	.03022
124	3.10000	-.10580	.12267	-.00620	.01211	.02256
125	3.12500	-.10868	.12120	-.00241	.00377	.01457
126	3.15000	-.11113	.11917	.00143	-.00466	.00635
127	3.17500	-.11314	.11657	.00518	-.01305	-.00200
128	3.20000	-.11470	.11343	.00874	-.02127	-.01034
129	3.22500	-.11583	.10978	.01199	-.02921	-.01855
130	3.25000	-.11650	.10566	.01482	-.03675	-.02651
131	3.27500	-.11671	.10110	.01715	-.04381	-.03413
132	3.30000	-.11641	.09617	.01893	-.05034	-.04130
133	3.32500	-.11555	.09092	.02012	-.05630	-.04796
134	3.35000	-.11405	.08540	.02072	-.06169	-.05409
135	3.37500	-.11182	.07967	.02075	-.06653	-.05965
136	3.40000	-.10872	.07374	.02025	-.07084	-.06467
137	3.42500	-.10463	.06766	.01927	-.07467	-.06916
138	3.45000	-.09941	.06142	.01789	-.07806	-.07316
139	3.47500	-.09294	.05504	.01618	-.08105	-.07671

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
140	3.50000	-.08513	.04850	.01422	-.08368	-.07985
141	3.52500	-.07591	.04181	.01208	-.08596	-.08261
142	3.55000	-.06529	.03497	.00983	-.08789	-.08500
143	3.57500	-.05331	.02798	.00752	-.08947	-.08705
144	3.60000	-.04012	.02086	.00518	-.09069	-.08874
145	3.62500	-.02590	.01366	.00284	-.09154	-.09007
146	3.65000	-.01094	.00641	.00051	-.09198	-.09103
147	3.67500	.00446	-.00084	-.00181	-.09203	-.09160
148	3.70000	.01993	-.00802	-.00413	-.09168	-.09177
149	3.72500	.03511	-.01508	-.00646	-.09094	-.09155
150	3.75000	.04963	-.02198	-.00880	-.08982	-.09094
151	3.77500	.06319	-.02870	-.01114	-.06836	-.08995
152	3.80000	.07551	-.03520	-.01345	-.08657	-.08862
153	3.82500	.08641	-.04151	-.01568	-.08447	-.08695
154	3.85000	.09581	-.04763	-.01779	-.08204	-.08496
155	3.87500	.10368	-.05358	-.01969	-.07929	-.08264
156	3.90000	.11010	-.05940	-.02128	-.07616	-.07999
157	3.92500	.11519	-.06510	-.02248	-.07259	-.07696
158	3.95000	.11911	-.07070	-.02318	-.06852	-.07351
159	3.97500	.12206	-.07619	-.02329	-.06387	-.06957
160	4.00000	.12419	-.08155	-.02277	-.05857	-.06507
161	4.02500	.12567	-.08674	-.02155	-.05255	-.05993
162	4.05000	.12659	-.09169	-.01964	-.04578	-.05411
163	4.07500	.12703	-.09635	-.01707	-.03828	-.04756
164	4.10000	.12701	-.10065	-.01391	-.03009	-.04030
165	4.12500	.12652	-.10452	-.01027	-.02131	-.03235
166	4.15000	.12550	-.10793	-.00628	-.01208	-.02381
167	4.17500	.12392	-.11085	-.00210	-.00258	-.01480
168	4.20000	.12173	-.11330	.00209	.00699	-.00548
169	4.22500	.11891	-.11529	.00614	.01642	.00396
170	4.25000	.11546	-.11688	.00986	.02552	.01333
171	4.27500	.11142	-.11811	.01312	.03410	.02242
172	4.30000	.10685	-.11902	.01580	.04203	.03106
173	4.32500	.10183	-.11964	.01781	.04922	.03912
174	4.35000	.09647	-.11994	.01910	.05562	.04649
175	4.37500	.09086	-.11987	.01965	.06125	.05311
176	4.40000	.08508	-.11931	.01948	.06615	.05898
177	4.42500	.07921	-.11808	.01865	.07043	.06415
178	4.45000	.07326	-.11599	.01723	.07417	.06867
179	4.47500	.06725	-.11278	.01532	.07749	.07264
180	4.50000	.06114	-.10821	.01303	.08048	.07615
181	4.52500	.05489	-.10204	.01049	.08319	.07930
182	4.55000	.04845	-.09407	.00780	.08568	.08214
183	4.57500	.04178	-.08420	.00506	.08793	.08472
184	4.60000	.03485	-.07238	.00235	.08992	.08705
185	4.62500	.02766	-.05870	-.00027	.09161	.08912
186	4.65000	.02024	-.04334	-.00278	.09293	.09088
187	4.67500	.01266	-.02663	-.00518	.09384	.09229

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
188	4.70000	.00500	-.00898	-.00749	.09428	.09330
189	4.72500	-.00264	.00911	-.00975	.09423	.09386
190	4.75000	-.01014	.02710	-.01201	.09372	.09396
191	4.77500	-.01741	.04442	-.01433	.09277	.09360
192	4.80000	-.02439	.06059	-.01673	.09144	.09282
193	4.82500	-.03105	.07517	-.01923	.08981	.09164
194	4.85000	-.03737	.08786	-.02181	.08794	.09015
195	4.87500	-.04340	.09850	-.02442	.08586	.08839
196	4.90000	-.04919	.10709	-.02696	.08361	.08641
197	4.92500	-.05484	.11374	-.02932	.08116	.08423
198	4.95000	-.06042	.11868	-.03134	.07843	.08183
199	4.97500	-.06599	.12220	-.03286	.07532	.07916
200	5.00000	-.07160	.12464	-.03371	.07168	.07611
201	5.02500	-.07725	.12631	-.03374	.06737	.07256
202	5.05000	-.08289	.12747	-.03284	.06223	.06838
203	5.07500	-.08844	.12831	-.03092	.05613	.06342
204	5.10000	-.09379	.12894	-.02799	.04902	.05755
205	5.12500	-.09881	.12935	-.02407	.04088	.05072
206	5.15000	-.10339	.12950	-.01929	.03178	.04290
207	5.17500	-.10742	.12925	-.01383	.02188	.03414
208	5.20000	-.11083	.12848	-.00789	.01139	.02458
209	5.22500	-.11361	.12705	-.00172	.00059	.01440
210	5.25000	-.11579	.12484	.00441	-.01022	.00386
211	5.27500	-.11746	.12182	.01024	-.02073	-.00677
212	5.30000	-.11874	.11798	.01555	-.03064	-.01719
213	5.32500	-.11976	.11341	.02013	-.03974	-.02712
214	5.35000	-.12064	.10824	.02384	-.04785	-.03633
215	5.37500	-.12146	.10262	.02657	-.05489	-.04465
216	5.40000	-.12224	.09673	.02828	-.06087	-.05198
217	5.42500	-.12291	.09073	.02897	-.06588	-.05829
218	5.45000	-.12331	.08475	.02871	-.07005	-.06365
219	5.47500	-.12319	.07894	.02761	-.07357	-.06817
220	5.50000	-.12222	.07301	.02581	-.07663	-.07200
221	5.52500	-.12002	.06723	.02347	-.07940	-.07532
222	5.55000	-.11622	.06140	.02076	-.08202	-.07830
223	5.57500	-.11043	.05540	.01785	-.08458	-.08106
224	5.60000	-.10236	.04911	.01490	-.08709	-.08369
225	5.62500	-.09182	.04243	.01202	-.08950	-.08623
226	5.65000	-.07876	.03532	.00929	-.09174	-.08867
227	5.67500	-.06328	.02776	.00677	-.09368	-.09092
228	5.70000	-.04567	.01982	.00444	-.09520	-.09289
229	5.72500	-.02639	.01163	.00228	-.09619	-.09447
230	5.75000	-.00603	.00334	.00021	-.09659	-.09557
231	5.77500	.01470	-.00487	-.00186	-.09636	-.09611
232	5.80000	.03503	-.01282	-.00401	-.09555	-.09607
233	5.82500	.05424	-.02037	-.00634	-.09425	-.09547
234	5.85000	.07167	-.02742	-.00890	-.09256	-.09437
235	5.87500	.08682	-.03393	-.01172	-.09064	-.09288

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
236	5.90000	.09939	-.03994	-.01479	-.08861	-.09111
237	5.92500	.10928	-.04553	-.01801	-.08657	-.08920
238	5.95000	.11662	-.05086	-.02128	-.08453	-.08721
239	5.97500	.12172	-.05607	-.02442	-.08248	-.08520
240	6.00000	.12499	-.06132	-.02724	-.08030	-.08314
241	6.02500	.12694	-.06674	-.02953	-.07779	-.08093
242	6.05000	.12805	-.07240	-.03108	-.07474	-.07843
243	6.07500	.12874	-.07828	-.03170	-.07090	-.07542
244	6.10000	.12934	-.08433	-.03127	-.06601	-.07167
245	6.12500	.13003	-.09039	-.02969	-.05988	-.06697
246	6.15000	.13088	-.09627	-.02697	-.05241	-.06112
247	6.17500	.13171	-.10177	-.02317	-.04358	-.05400
248	6.20000	.13242	-.10669	-.01844	-.03350	-.04559
249	6.22500	.13273	-.11087	-.01299	-.02239	-.03596
250	6.25000	.13237	-.11421	-.00709	-.01057	-.02531
251	6.27500	.13112	-.11672	-.00102	.00156	-.01391
252	6.30000	.12883	-.11846	.00493	.01359	-.00211
253	6.32500	.12544	-.11960	.01050	.02509	.00969
254	6.35000	.12102	-.12035	.01544	.03570	.02110
255	6.37500	.11571	-.12094	.01957	.04513	.03176
256	6.40000	.10975	-.12159	.02273	.05321	.04138
257	6.42500	.10340	-.12246	.02484	.05991	.04977
258	6.45000	.09693	-.12360	.02586	.06529	.05687
259	6.47500	.09056	-.12494	.02581	.06954	.06271
260	6.50000	.08444	-.12627	.02479	.07292	.06742
261	6.52500	.07863	-.12723	.02290	.07571	.07123
262	6.55000	.07308	-.12738	.02032	.07820	.07439
263	6.57500	.06769	-.12620	.01722	.08062	.07715
264	6.60000	.06225	-.12313	.01383	.08314	.07975
265	6.62500	.05656	-.11769	.01031	.08584	.08236
266	6.65000	.05040	-.10948	.00686	.08868	.08506
267	6.67500	.04364	-.09823	.00361	.09155	.08785
268	6.70000	.03619	-.08390	.00065	.09428	.09066
269	6.72500	.02808	-.06663	-.00198	.09665	.09334
270	6.75000	.01941	-.04681	-.00427	.09847	.09570
271	6.77500	.01039	-.02507	-.00629	.09957	.09758
272	6.80000	.00128	-.00218	-.00814	.09986	.09881
273	6.82500	-.00764	.02092	-.00995	.09933	.09929
274	6.85000	-.01612	.04326	-.01185	.09805	.09901
275	6.87500	-.02395	.06394	-.01400	.09619	.09801
276	6.90000	-.03101	.08219	-.01647	.09396	.09643
277	6.92500	-.03728	.09746	-.01933	.09157	.09444
278	6.95000	-.04285	.10948	-.02257	.08923	.09224
279	6.97500	-.04788	.11829	-.02609	.08709	.09001
280	7.00000	-.05262	.12417	-.02975	.08519	.08790
281	7.02500	-.05730	.12764	-.03331	.08349	.08596
282	7.05000	-.06219	.12931	-.03653	.08180	.08417
283	7.07500	-.06746	.12988	-.03912	.07988	.08238

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
284	7.10000	-.07321	.12936	-.04078	.07739	.08038
285	7.12500	-.07942	.13005	-.04128	.07396	.07786
286	7.15000	-.08598	.13050	-.04041	.06926	.07451
287	7.17500	-.09266	.13142	-.03807	.06303	.07000
288	7.20000	-.09918	.13273	-.03425	.05511	.06408
289	7.22500	-.10523	.13433	-.02906	.04551	.05660
290	7.25000	-.11053	.13575	-.02269	.03439	.04753
291	7.27500	-.11487	.13664	-.01544	.02203	.03697
292	7.30000	-.11811	.13663	-.00767	.00889	.02519
293	7.32500	-.12028	.13543	.00024	-.00453	.01257
294	7.35000	-.12149	.13287	.00792	-.01767	-.00044
295	7.37500	-.12199	.12891	.01503	-.03002	-.01332
296	7.40000	-.12209	.12372	.02128	-.04113	-.02558
297	7.42500	-.12214	.11753	.02643	-.05069	-.03680
298	7.45000	-.12247	.11072	.03033	-.05856	-.04664
299	7.47500	-.12329	.10365	.03291	-.06472	-.05493
300	7.50000	-.12470	.09668	.03414	-.06936	-.06162
301	7.52500	-.12663	.09008	.03410	-.07277	-.06684
302	7.55000	-.12879	.08400	.03291	-.07530	-.07081
303	7.57500	-.13073	.07848	.03076	-.07737	-.07385
304	7.60000	-.13188	.07339	.02787	-.07933	-.07632
305	7.62500	-.13156	.06851	.02449	-.08147	-.07856
306	7.65000	-.12910	.06355	.02086	-.08398	-.08084
307	7.67500	-.12387	.05817	.01722	-.08689	-.08337
308	7.70000	-.11539	.05211	.01374	-.09012	-.08620
309	7.72500	-.10337	.04516	.01056	-.09348	-.08930
310	7.75000	-.08774	.03723	.00777	-.09668	-.09251
311	7.77500	-.06874	.02840	.00537	-.09944	-.09560
312	7.80000	-.04686	.01885	.00334	-.10148	-.09832
313	7.82500	-.02287	.00888	.00157	-.10259	-.10042
314	7.85000	.00224	-.00112	-.00007	-.10268	-.10169
315	7.87500	.02734	-.01079	-.00175	-.10175	-.10203
316	7.90000	.05129	-.01977	-.00364	-.09995	-.10143
317	7.92500	.07302	-.02782	-.00588	-.09751	-.09998
318	7.95000	.09169	-.03480	-.00857	-.09473	-.09789
319	7.97500	.10675	-.04074	-.01175	-.09193	-.09541
320	8.00000	.11800	-.04576	-.01540	-.08938	-.09281
321	8.02500	.12562	-.05014	-.01938	-.08725	-.09035
322	8.05000	.13007	-.05421	-.02351	-.08561	-.08821
323	8.07500	.13207	-.05834	-.02755	-.08436	-.08646
324	8.10000	.13242	-.06285	-.03122	-.08327	-.08504
325	8.12500	.13198	-.06800	-.03421	-.08198	-.08376
326	8.15000	.13141	-.07388	-.03625	-.08006	-.08231
327	8.17500	.13130	-.08048	-.03708	-.07703	-.08031
328	8.20000	.13194	-.08760	-.03652	-.07247	-.07734
329	8.22500	.13338	-.09494	-.03449	-.06608	-.07299
330	8.25000	.13544	-.10212	-.03100	-.05767	-.06697
331	8.27500	.13776	-.10874	-.02619	-.04727	-.05908

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
332	8.30000	.13986	-.11442	-.02029	-.03509	-.04931
333	8.32500	.14122	-.11890	-.01361	-.02154	-.03782
334	8.35000	.14139	-.12203	-.00651	-.00716	-.02496
335	8.37500	.14002	-.12394	.00065	.00740	-.01119
336	8.40000	.13696	-.12452	.00751	.02148	.00290
337	8.42500	.13226	-.12438	.01378	.03449	.01671
338	8.45000	.12616	-.12384	.01920	.04592	.02966
339	8.47500	.11905	-.12337	.02359	.05546	.04126
340	8.50000	.11139	-.12336	.02680	.06298	.05117
341	8.52500	.10368	-.12412	.02876	.06856	.05923
342	8.55000	.09633	-.12577	.02946	.07247	.06546
343	8.57500	.08965	-.12819	.02893	.07510	.07005
344	8.60000	.08377	-.13106	.02729	.07694	.07334
345	8.62500	.07866	-.13381	.02471	.07848	.07574
346	8.65000	.07411	-.13576	.02139	.08015	.07770
347	8.67500	.06977	-.13603	.01758	.08227	.07962
348	8.70000	.06525	-.13402	.01352	.08500	.08182
349	8.72500	.06012	-.12882	.00945	.08834	.08449
350	8.75000	.05402	-.11995	.00557	.09214	.08767
351	8.77500	.04674	-.10708	.00204	.09610	.09124
352	8.80000	.03819	-.09020	-.00104	.09985	.09498
353	8.82500	.02851	-.06958	-.00363	.10302	.09857
354	8.85000	.01798	-.04585	-.00576	.10525	.10168
355	8.87500	.00702	-.01992	-.00751	.10632	.10400
356	8.90000	-.00389	.00704	-.00905	.10613	.10528
357	8.92500	-.01428	.03375	-.01056	.10473	.10541
358	8.95000	-.02371	.05888	-.01224	.10233	.10442
359	8.97500	-.03191	.08129	-.01429	.09925	.10246
360	9.00000	-.03874	.10007	-.01685	.09589	.09980
361	9.02500	-.04426	.11472	-.01998	.09263	.09677
362	9.05000	-.04870	.12512	-.02367	.08980	.09373
363	9.07500	-.05240	.13159	-.02778	.08763	.09099
364	9.10000	-.05581	.13477	-.03211	.08617	.08876
365	9.12500	-.05941	.13555	-.03638	.08527	.08711
366	9.15000	-.06358	.13489	-.04024	.08464	.08596
367	9.17500	-.06864	.13373	-.04334	.08384	.08506
368	9.20000	-.07470	.13284	-.04531	.08231	.08403
369	9.22500	-.08170	.13276	-.04585	.07951	.08239
370	9.25000	-.08939	.13375	-.04474	.07495	.07964
371	9.27500	-.09739	.13576	-.04185	.06826	.07531
372	9.30000	-.10520	.13849	-.03722	.05927	.06904
373	9.32500	-.11234	.14144	-.03102	.04803	.06066
374	9.35000	-.11837	.14403	-.02354	.03483	.05015
375	9.37500	-.12296	.14563	-.01517	.02016	.03774
376	9.40000	-.12598	.14573	-.00636	.00467	.02385
377	9.42500	-.12746	.14399	.00244	-.01087	.00904
378	9.45000	-.12764	.14030	.01082	-.02573	-.00600
379	9.47500	-.12693	.13479	.01841	-.03922	-.02057

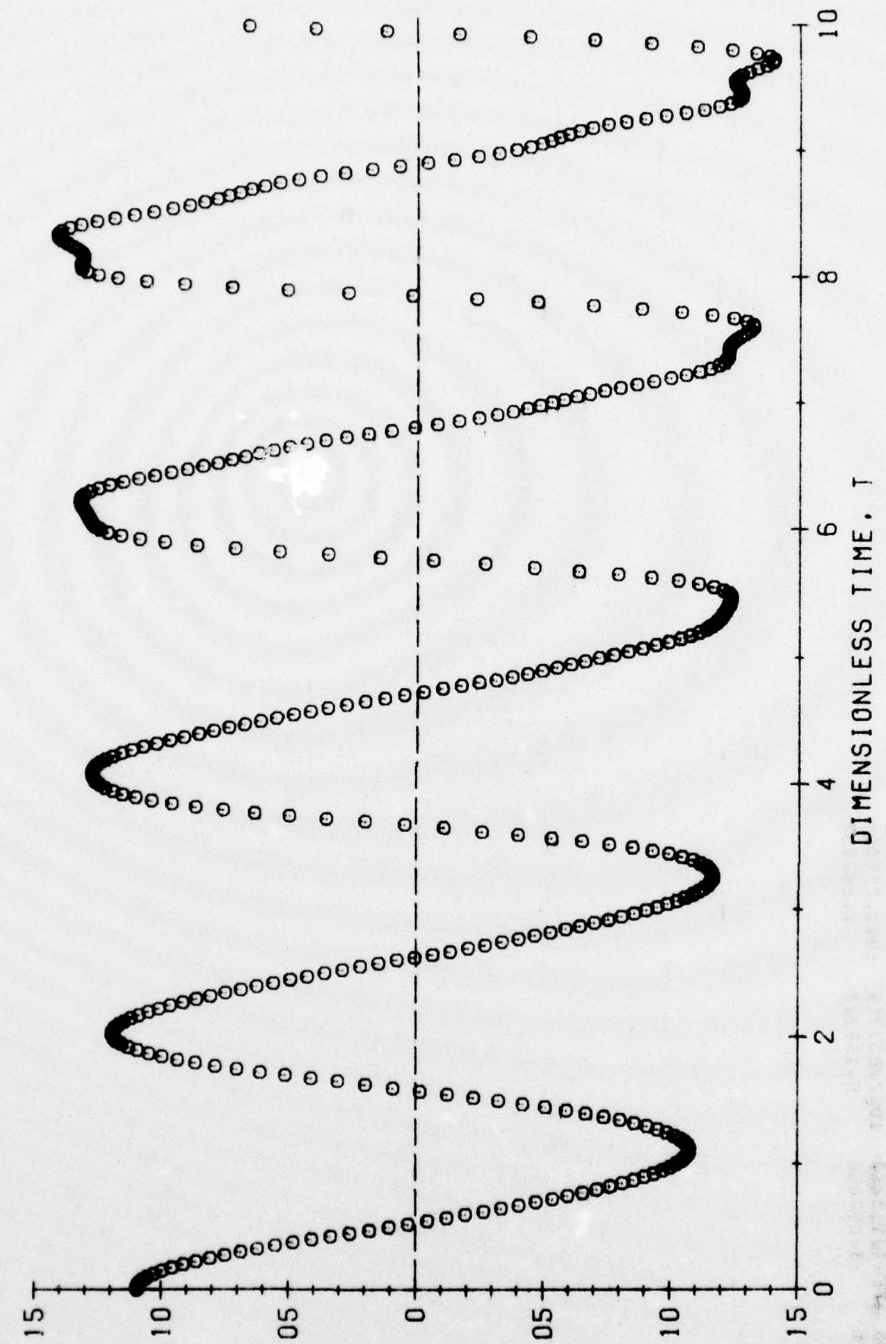
STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
380	9.50000	-.12583	.12780	.02493	-.05083	-.03404
381	9.52500	-.12490	.11985	.03018	-.06023	-.04588
382	9.55000	-.12462	.11150	.03400	-.06733	-.05575
383	9.57500	-.12535	.10334	.03635	-.07231	-.06351
384	9.60000	-.12719	.09591	.03724	-.07550	-.06924
385	9.62500	-.13004	.08924	.03674	-.07742	-.07321
386	9.65000	-.13348	.08370	.03503	-.07862	-.07585
387	9.67500	-.13687	.07909	.03232	-.07969	-.07766
388	9.70000	-.13939	.07510	.02888	-.08111	-.07916
389	9.72500	-.14014	.07129	.02498	-.08320	-.08080
390	9.75000	-.13823	.06714	.02091	-.08611	-.08291
391	9.77500	-.13287	.06214	.01689	-.08979	-.08569
392	9.80000	-.12348	.05589	.01314	-.09402	-.08912
393	9.82500	-.10972	.04815	.00978	-.09841	-.09305
394	9.85000	-.09160	.03890	.00689	-.10252	-.09717
395	9.87500	-.06948	.02833	.00448	-.10590	-.10109
396	9.90000	-.04410	.01681	.00250	-.10818	-.10442
397	9.92500	-.01650	.00489	.00082	-.10910	-.10679
398	9.95000	.01200	-.00685	-.00073	-.10858	-.10797
399	9.97500	.03997	-.01785	-.00234	-.10673	-.10784
400	10.00000	.06597	-.02763	-.00423	-.10382	-.10647
401	10.02500	.08879	-.03588	-.00655	-.10024	-.10405

PRESSURE MAXIMA AND MINIMA AT: Z = 0.00
VALUES COMPUTED: 14

.109688	-.107549	.119760	-.116711	.127082	-.123326	.132730	-.131939
.014273	1.111258	2.028960	3.272649	4.086373	5.456670	6.224028	7.607045
.132426	.131253	.141505	-.127679	-.124600	-.140207		
8.098397	8.166175	8.340156	9.442609	9.544475	9.719569		

PRESSURE GROWTH RATE AND FREQUENCY.
TOTAL NUMBER OF CYCLES: 4

93.401216	61.785102	43.567280	64.804178
1063.192733	1041.113233	1002.032711	1012.225881
1.021616	3.057666	5.155200	7.282092


HEAD END PRESSURE PERTURBATION
0.15
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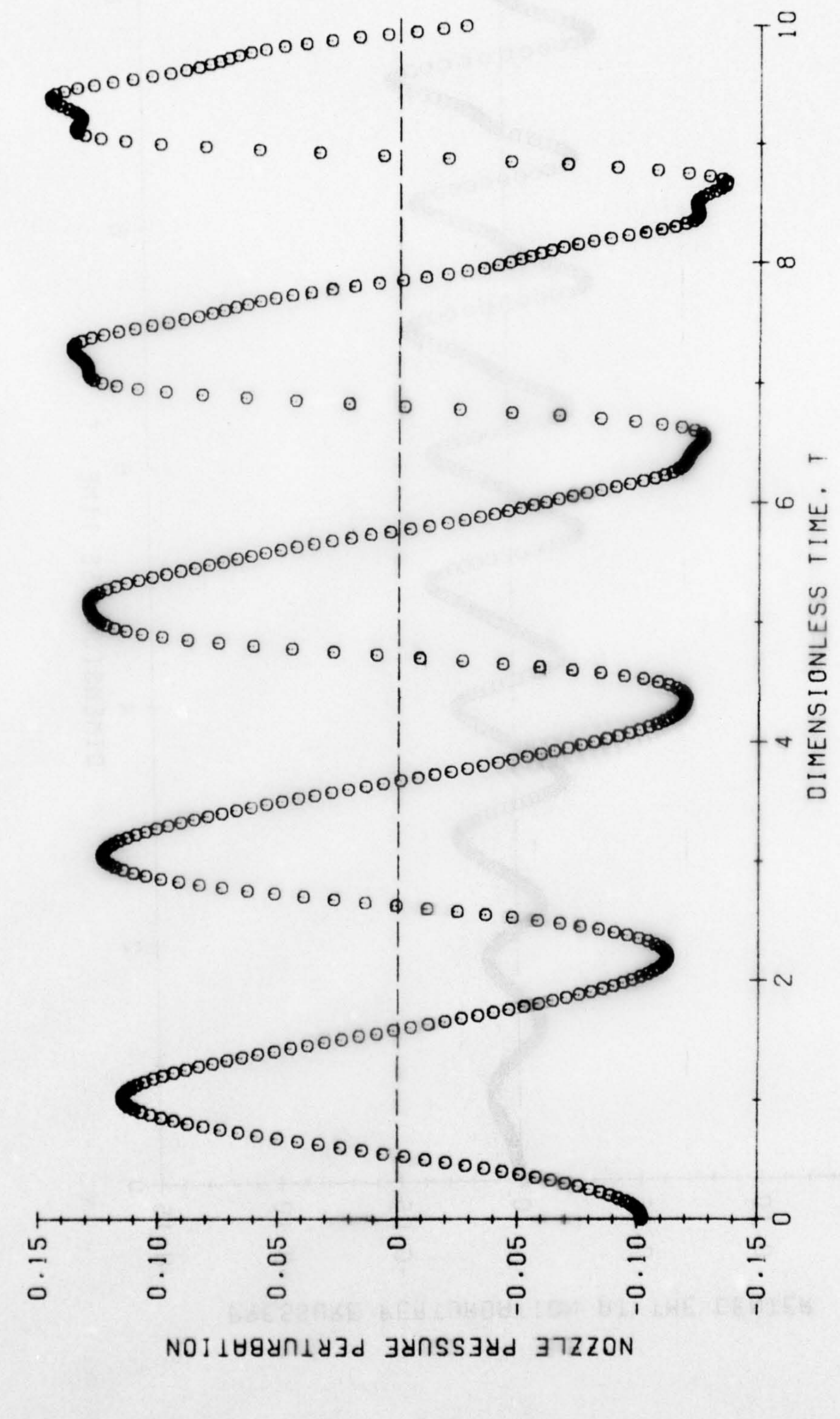
-0.10
-0.15
0
2
4
6
8
10
DIMENSIONLESS TIME, T


NOZZLE PRESSURE PERTURBATION
DIMENSIONLESS TIME, T
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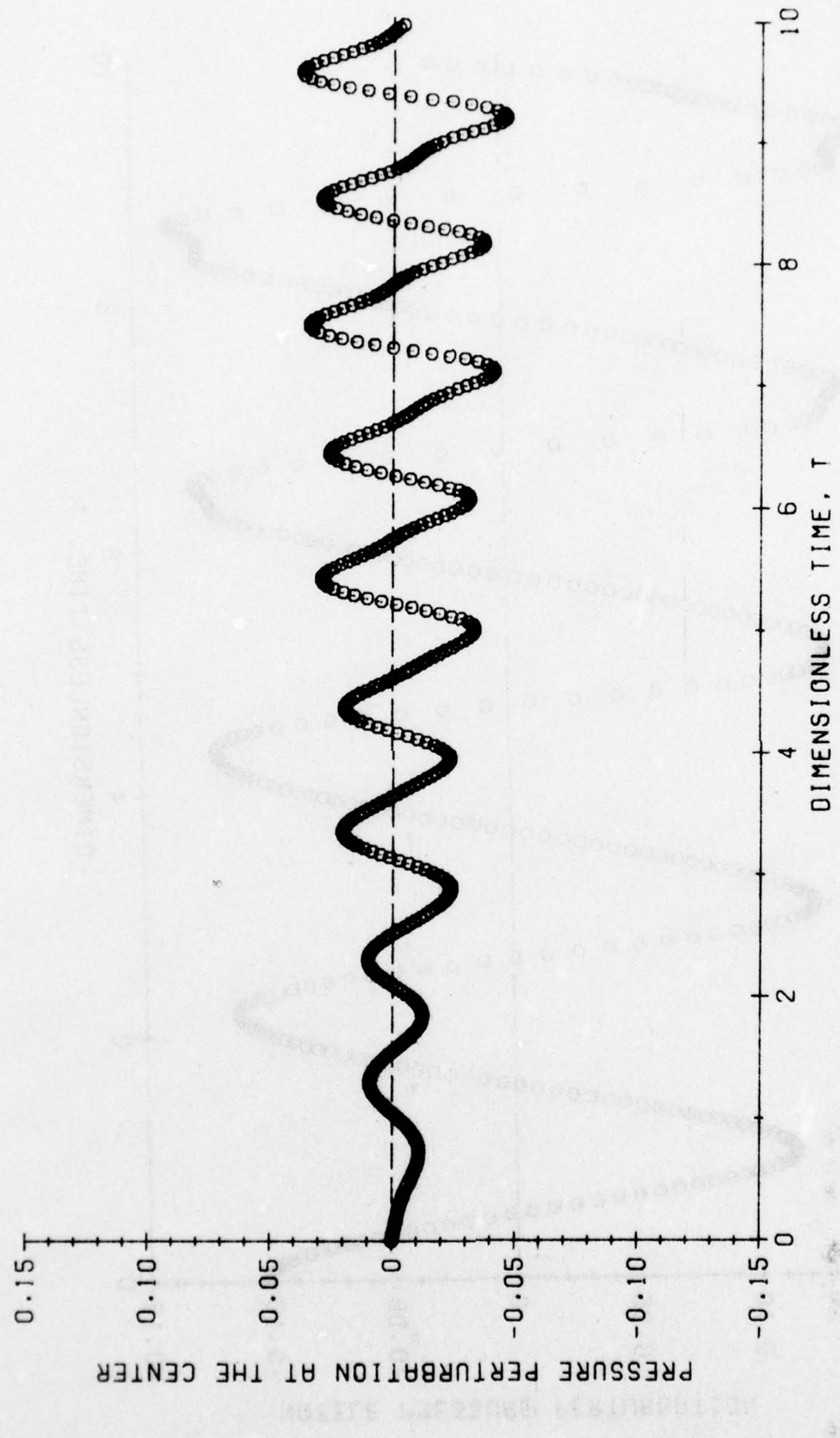
0.05
0
-0.05
-0.10
-0.15
0
2
4
6
8
10


PRESSURE PERTURBATION AT THE CENTER
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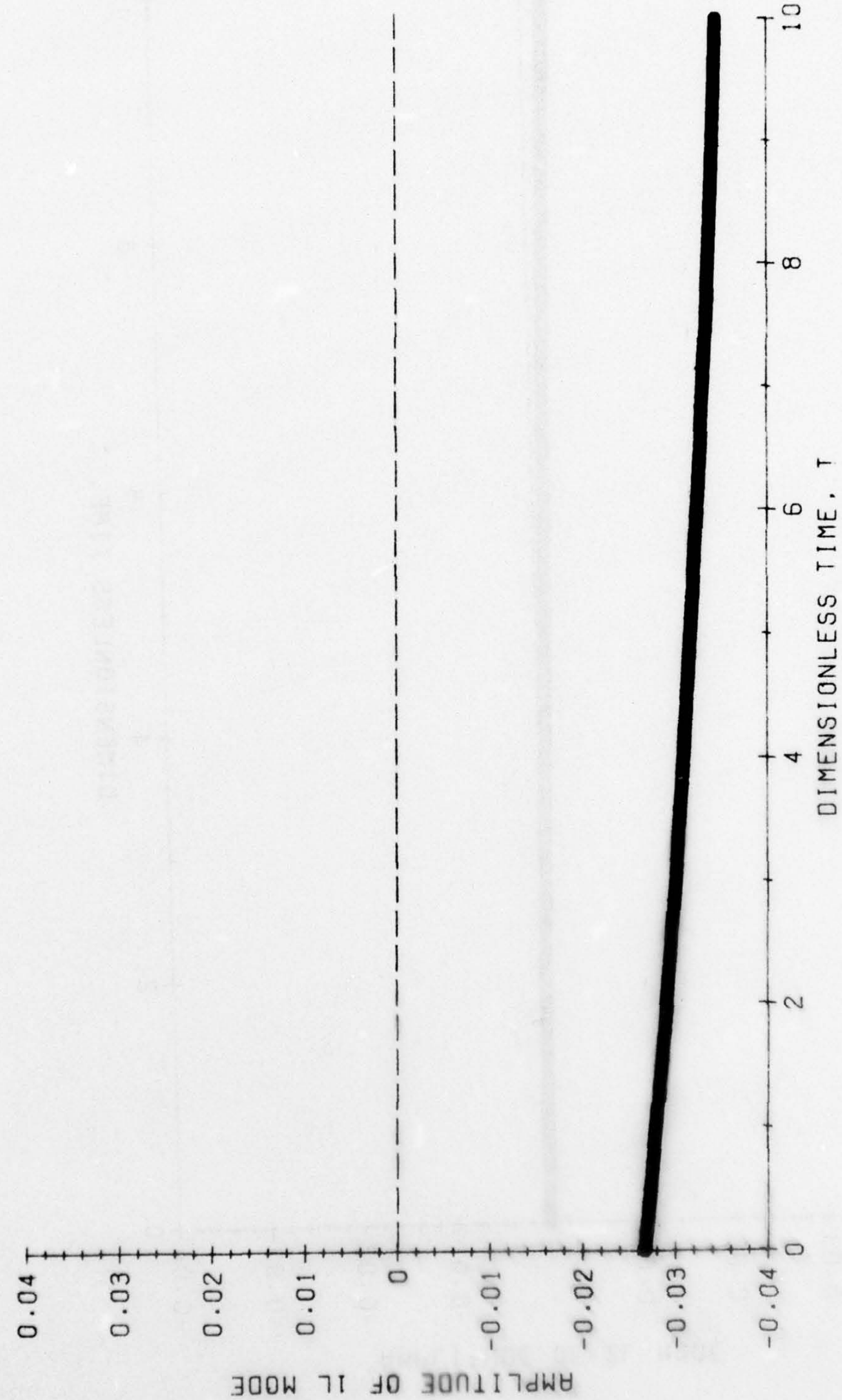
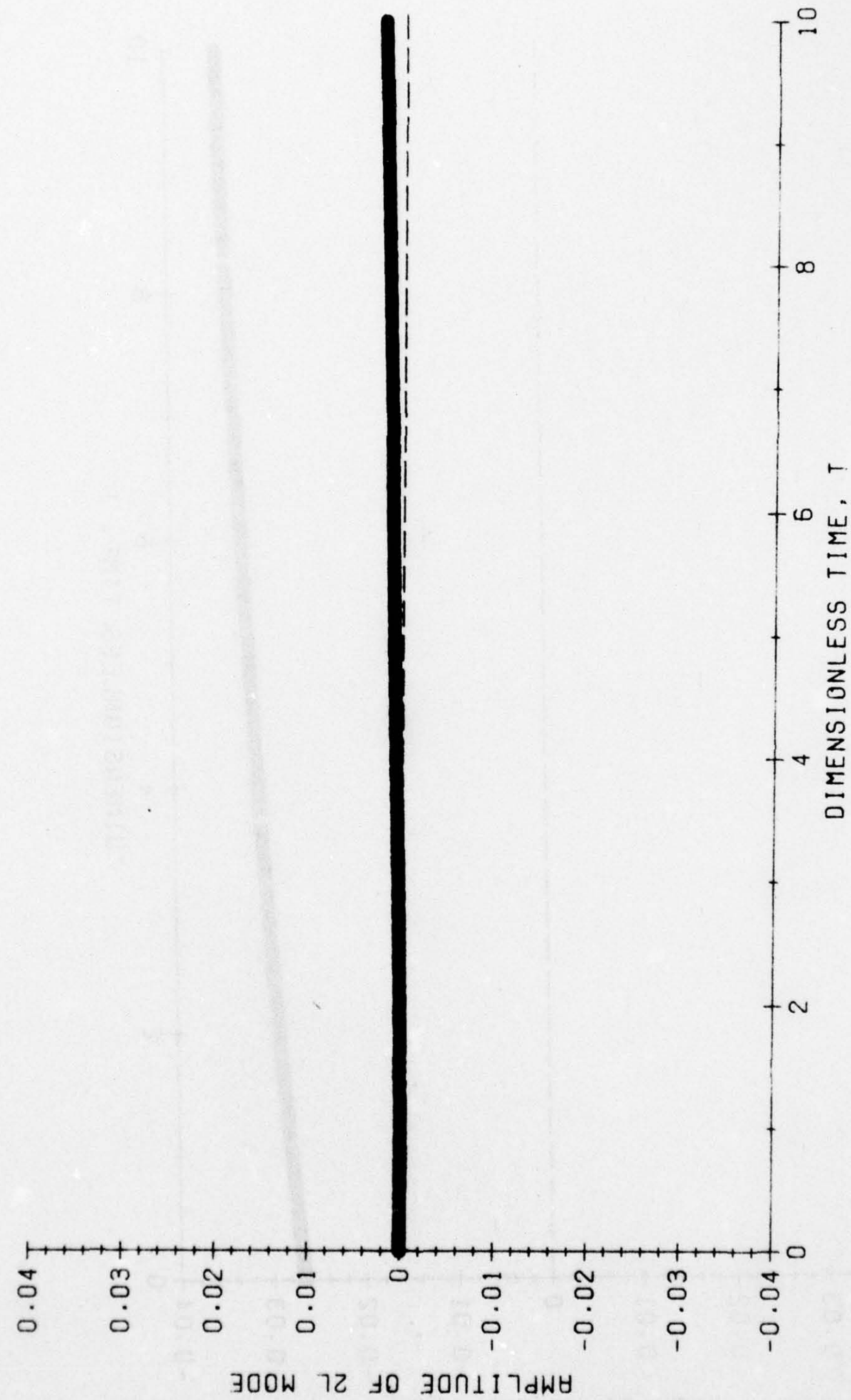
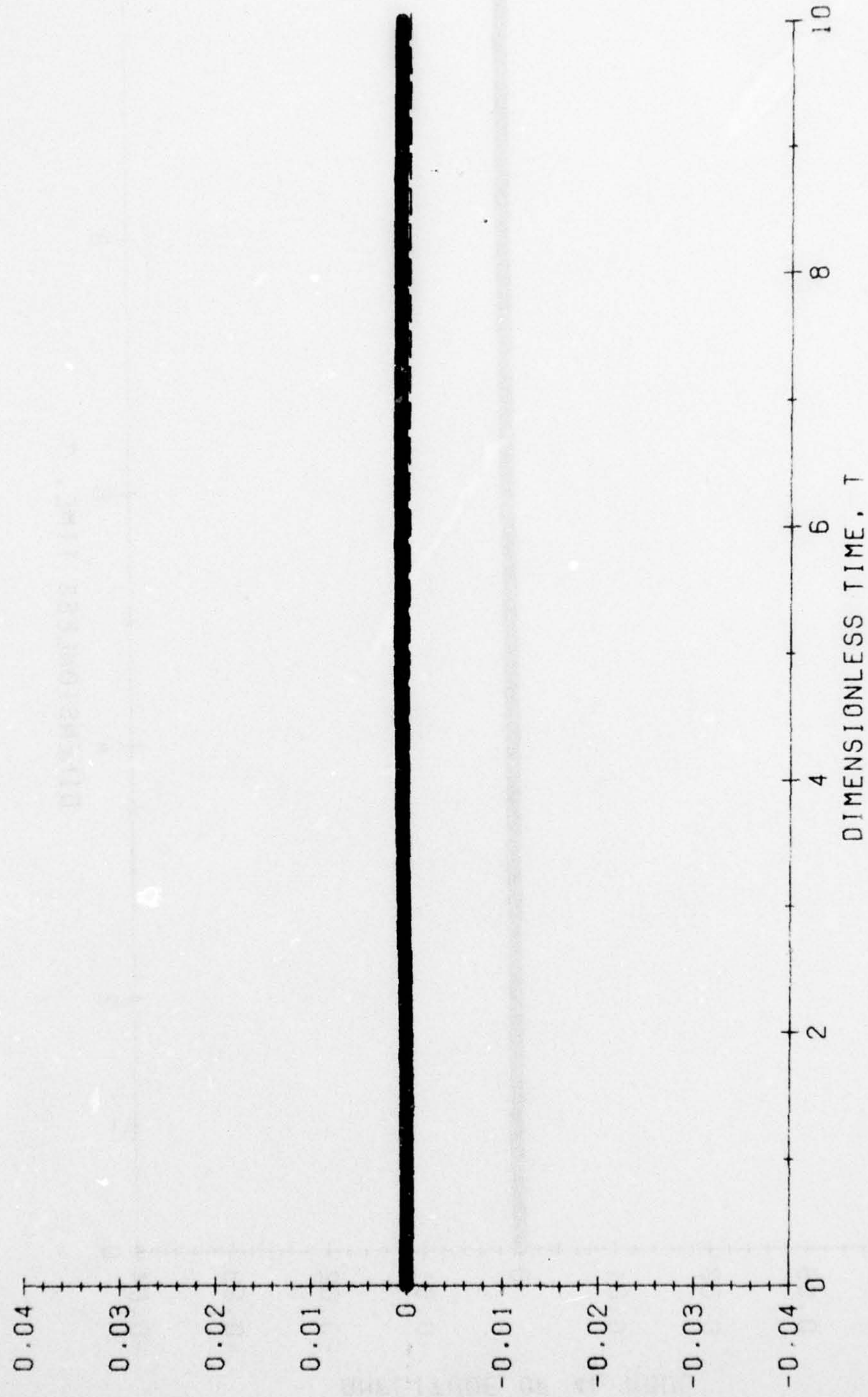
0.05
0
-0.05
-0.10
-0.15
0
2
4
6
8
10
DIMENSIONLESS TIME, T

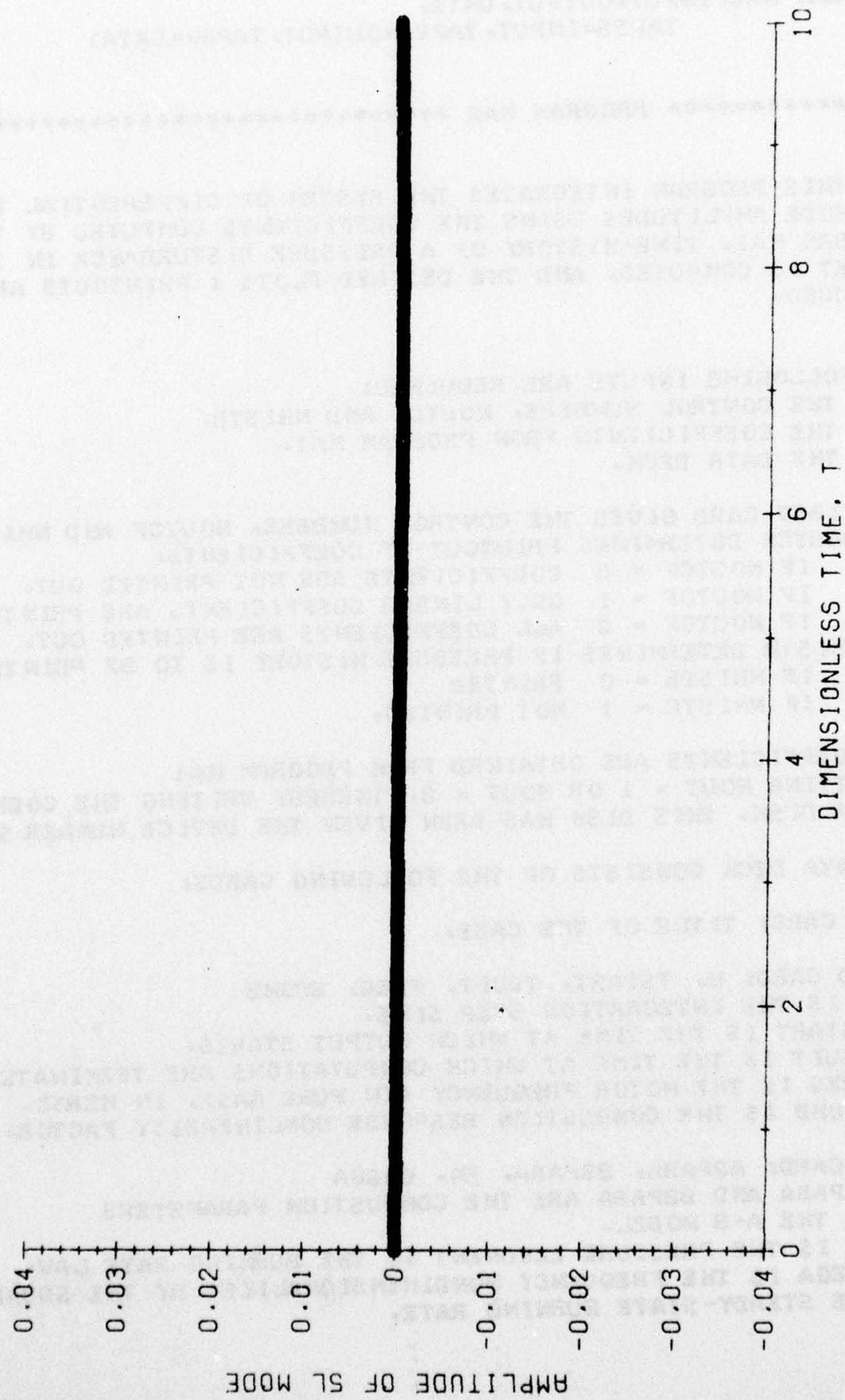

AMPLITUDE OF 1L MODE
DIMENSIONLESS TIME, T
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
2
4
6
8
10


AMPLITUDE OF 2L MODE
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
DIMENSIONLESS TIME, T
0
2
4
6
8
10



AMPLITUDE OF 3L MODE
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
0
2
4
6
8
10
DIMENSIONLESS TIME, T

AMPLITUDE OF 4L MODE
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
0
2
4
6
8
10
DIMENSIONLESS TIME, T



DIMENSIONLESS TIME, T
0
2
4
6
8
10
AMPLITUDE OF SL MODE
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04

FORTRAN Source Code.

```
      PROGRAM MA2(INPUT,OUTPUT,DATA,
     1                TAPE5=INPUT,TAPE6=OUTPUT,TAPE9=DATA)
C
C
C     *************** PROGRAM MA2 *********************************
C
C
C         THIS PROGRAM INTEGRATES THE SYSTEM OF DIFFERENTIAL EQUATIONS
C     FOR MODE AMPLITUDES USING THE COEFFICIENTS COMPUTED BY THE
C     PROGRAM MA1. TIME-HISTORY OF A PRESSURE DISTURBANCE IN THE
C     ROCKET IS COMPUTED, AND THE DESIRED PLOTS & PRINTOUTS ARE
C     PRODUCED.
C
C
C     THE FOLLOWING INPUTS ARE REQUIRED:
C     (1)  THE CONTROL NUMBERS, NOUTCF AND NHISTR.
C     (2)  THE COEFFICIENTS FROM PROGRAM MA1.
C     (3)  THE DATA DECK.
C
C     THE FIRST CARD GIVES THE CONTROL NUMBERS, NOUTCF AND NHISTR.
C          NOUTCF DETERMINES PRINTOUT OF COEFFICIENTS:
C             IF NOUTCF = 0  COEFFICIENTS ARE NOT PRINTED OUT.
C             IF NOUTCF = 1  ONLY LINEAR COEFFICIENTS ARE PRINTED OUT.
C             IF NOUTCF = 2  ALL COEFFICIENTS ARE PRINTED OUT.
C          NHISTR DETERMINES IF PRESSURE HISTORY IS TO BE PRINTED:
C             IF NHISTR = 0  PRINTED
C             IF NHISTR = 1  NOT PRINTED.
C
C     THE COEFFICIENTS ARE OBTAINED FROM PROGRAM MA1
C     BY PUTTING NOUT = 1 OR NOUT = 2, THEREBY WRITING THE COEFFICIENTS
C     INTO A DISK. THIS DISK HAS BEEN GIVEN THE DEVICE NUMBER 9.
C
C     THE DATA DECK CONSISTS OF THE FOLLOWING CARDS:
C
C     FIRST CARD: TITLE OF THE CASE.
C
C     SECOND CARD: H, TSTART, TQUIT, FREQ, BCOMB
C          H IS THE INTEGRATION STEP SIZE.
C          TSTART IS THE TIME AT WHICH OUTPUT STARTS.
C          TQUIT IS THE TIME AT WHICH COMPUTATIONS ARE TERMINATED.
C          FREQ IS THE MOTOR FREQUENCY (IN PURE GAS), IN HERTZ.
C          BCOMB IS THE COMBUSTION RESPONSE NONLINEARITY FACTOR.
C
C     THIRD CARD: A2PARA, B2PARA, EN, OMEGA
C          A2PARA AND B2PARA ARE THE COMBUSTION PARAMETERS
C          IN THE A-B MODEL.
C          EN IS THE PRESSURE EXPONENT IN THE BURNING RATE LAW.
C          OMEGA IS THE FREQUENCY NONDIMENSIONALIZED BY THE SQUARE OF
C          THE STEADY-STATE BURNING RATE.
C
```

```
C      FOURTH CARD: NLOC, NTERMS, NOUT, NCOMB
C          NLOC DETERMINES THE LOCATION OF THE WALL PRESSURE MAXIMA
C          AND MINIMA:
C              IF NLOC = 1        LOCATION IS Z = 0.0
C              IF NLOC = 2        LOCATION IS Z = 1.0
C              IF NLOC = 3        LOCATION IS Z = 0.5
C          NTERMS IS THE NUMBER OF TERMS GIVEN INITIAL VALUES.
C          NOUT IS THE OUTPUT CONTROL NUMBER.
C              IF NOUT = 0        PRINTED OUTPUT ONLY.
C              IF NOUT > 0        BOTH PRINTED AND PLOTTED OUTPUT;
C              IF NOUT = 1        PLOT OF PRESSURE AT Z = 0.0 ONLY.
C              IF NOUT = 2        PLOT OF PRESSURE AT Z = 0.0 AND Z = 1.0
C              IF NOUT = 3        PLOT OF PRESSURE AT Z = 0.0, 1.0 AND 0.5.
C          NCOMB DETERMINES IF COMBUSTION NONLINEARITIES ARE CONSIDERED:
C              IF NCOMB = 0        NEGLECTED.
C              IF NCOMB = 1        INCLUDED.
C
C      NEXT CARD (NECESSARY ONLY IF PLOTS ARE REQUIRED): YHI, YLAB, ITICY
C          YHI IS THE MAXIMUM ORDINATE FOR PRESSURE PLOTS.
C          NOTE: THE ORDINATE SCALES FOR PRESSURE AND AMPLITUDE PLOTS
C                ARE SYMMETRIC ABOUT ZERO.
C          YLAB IS THE INTERVAL FOR ORDINATE LABELING FOR ABOVE PLOTS.
C          ITICY IS THE NUMBER OF ORDINATE TIC MARKS FOR ABOVE PLOTS.
C          NOTE: ITICY SHOULD BE NEGATIVE FOR PRESSURE AND AMPLITUDE
C                PLOTS TO OBTAIN CENTERLINE.
C
C      NEXT CARD (NECESSARY ONLY IF PLOTS ARE REQUIRED): MDPLOT
C          MDPLOT DETERMINES IF PLOTS OF INDIVIDUAL MODES ARE REQUIRED:
C             IF PLOT OF J TH MODE IS REQUIRED, PUNCH "1" IN THE
C             5*J TH COLUMN.
C             IF PLOT OF J TH MODE IS NOT REQUIRED, PUNCH "0" IN THE
C             5*J TH COLUMN.
C
C      NEXT CARD (NECESSARY ONLY IF PLOT OF ANY MODE AMPLITUDE IS
C      REQUIRED): YHIMD, YLABMD, ITICMD
C          YHIMD IS THE MAXIMUM ORDINATE.
C          YLABMD IS THE INTERVAL FOR ORDINATE LABELLING.
C          ITICMD IS THE NUMBER OF ORDINATE TIC MARKS FOR MODE PLOTS.
C          NOTE: ITICMD SHOULD BE NEGATIVE TO OBTAIN CENTERLINE.
C
C      REMAINING CARDS (NTERMS IN NUMBER): J, AST, ACT
C          AST IS THE AMPLITUDE OF THE SINE TERM OF THE J TH MODE.
C          ACT IS THE AMPLITUDE OF THE COSINE TERM OF THE J TH MODE.
C
C      ******************************************************************
C
C
```

```
      COMPLEX     YNOZ(6), B(6), C1, C3, RES(6), CRES
      DIMENSION   L(6), NAME(6), AA(4), DELTA(6,6), YI(12),
     1            YR(12), CP(3,12,12), E(12,12,2), UMA(24),
     2            CFT(3,12), CFZ(3,12), AS(12), BETA1(6,6,6),
     3            AC(12), U(5,24), Y(24),PRESS(3), BETA2(6,6,6),
     4            YP(24), FZ(4,24), UZ(24),Z(3), TIMAX(500),
     5            TPLOT(500), YPLOT(3,500), DUMMYT(500), DUMMYY(500),
     6            IBUF(512), ITT(3), ITY1(3),ITY2(3),ITY3(4),
     7            ITP(2),  TITLE(7), PRS(500), TI(500), PMAX(500),
     8            MDPLOT(6), UPLOT(6,500), MTITL1(2), MTITL2(2),
     9            MTITL3(2), MTITL4(2), MTITL5(2), MTITL6(2), MTITL(2)
C
      COMMON      C(2,24,12), D(4,12,144), KPMAX(2,24), IC(2,24,12),
     1            KPQMAX(12), IDP(12,144), IDQ(12,144)
      COMMON      /BLK2/      B
      COMMON      /BLK3/      NPRTKL, NJMAX, NLMAX, GAMMA, COEF(2,12)
      COMMON      /BLK4/      PARTKL, RHOP, FRQ1(12)
      COMMON      /BLK5/      RES, NCOMB, BCOMB, E
C
      DATA      ITT/"DIMENSIONL","ESS TIME, ","T         "/,
     1          ITY1/"HEAD END P","RESSURE PE","RTURBATION"/,
     2          ITY2/"NOZZLE PRE","SSURE PERT","URBATION  "/,
     3          ITY3/"PRESSURE P","ERTURBATIO","N AT THE C","ENTER     "/,
     4          ITP/"PRESSURE P","EAKS      "/,
     5          MTITL1/"AMPLITUDE ","OF 1L MODE"/,
     6          MTITL2/"AMPLITUDE ","OF 2L MODE"/,
     7          MTITL3/"AMPLITUDE ","OF 3L MODE"/,
     8          MTITL4/"AMPLITUDE ","OF 4L MODE"/,
     9          MTITL5/"AMPLITUDE ","OF 5L MODE"/,
     1          MTITL6/"AMPLITUDE ","OF 6L MODE"/
C
      MAXMD = 6
      MAXMD2 = 12
      MAXMD4 = 24
      MAXMD6 = 36
      MAXMDD = 144
      LAST = 5
      ERR = 0.001
      TDEL = 10.0
      NPT = 0
      AA(1) = 0.0
      AA(2) = 0.5
      AA(3) = 0.5
      AA(4) = 1.0
      PI = 3.1415926536
      HC = 1.0
      READ (5,5003) NOUTCF, NHISTR
C
C     ************* COEFFICIENT INPUT SECTION ***************************
C
C     THIS VERSION OF MA2 READS THE COEFFICIENT DATA FROM
C     A FILE GENERATED BY PROGRAM MA1.  TO READ
C     THIS DATA FROM CARDS, USE READ (5,XXXX) INSTEAD OF
C     READ (9,XXXX) IN THIS SECTION.
```

```
C
C     INPUT OF MOTOR PARAMETERS AND NUMBER OF TERMS.
      READ (9,5001)  GAMMA, UE, ZE, NJMAX, NPRTKL
      RHOP = 0.0
      PARTKL = 0.0
      UPBYU = 0.0
      JMX = NJMAX/2
      NU = 2 * NJMAX
      GAM = GAMMA
      FRATIO = 1.0
      IF (NPRTKL .EQ. 0) GO TO 14
      READ (9,5011) DIA, RHOM, SP, TEMP, FREQ, PARTKL, CM
      UPBYU = 2.0/(1.0 + SQRT(1.0 + 8.0 * UE/PARTKL))
      RHOP = CM/UPBYU
      GAM = GAMMA / (1.0 + SP*CM - SP*CM*GAMMA)
      FRATIO = SQRT(GAMMA/(GAM*(1.0 + CM)))
   14 CONTINUE
C
      WRITE (6,6001) UE, JMX, GAM
      IF (NPRTKL .EQ. 0) WRITE (6,6033)
      IF (NPRTKL .EQ. 1) WRITE (6,6009) GAMMA
      IF (NPRTKL .EQ. 1) WRITE (6,6030) DIA, CM, FREQ, TEMP,
     1    SP, RHOM, PARTKL
      WRITE (6,6002)
C
C     INPUT OF DESCRIPTION OF SERIES EXPANSION.
      DO 10 K = 1, JMX
      READ (9,5002) NJ, L(NJ), NAME(NJ)
      WRITE (6,6003)  NAME(NJ), NJ, L(NJ)
   10 CONTINUE
C
      WRITE (6,6010)
      DO 15 K = 1, JMX
      READ (9,5010) J, YNOZ(J), B(J)
      WRITE (6,6015) J, YNOZ(J), B(J)
      NJ = (2 * J) - 1
      YR(NJ) = REAL(YNOZ(J))
      YI(NJ) = AIMAG(YNOZ(J))
      YR(NJ+1) = YR(NJ)
      YI(NJ+1) = YI(NJ)
   15 CONTINUE
C
      DO 402 K = 1, JMX
      J = 2*K - 1
      AX = L(K) * PI * FRATIO / ZE
      FRQ1(J) = AX
      FRQ1(J+1) = AX
  402 CONTINUE
C
```

```
      DO 404 NJ = 1, JMX
      DO 404 NP = 1, JMX
      DELTA(NJ,NP) = 0.0
      IF (NJ .EQ. NP) DELTA(NJ,NP) = 1.0
  404 CONTINUE
      PIBY2 = PI/2.
      DO 406 NJ = 1, JMX
      DO 406 NP = 1, JMX
      DO 406 NQ = 1, JMX
      IF (NP .NE. NQ+NJ) GO TO 408
      BETA1(NP,NQ,NJ) = PIBY2
      BETA2(NP,NQ,NJ) = - PIBY2
      GO TO 406
  408 IF (NQ .NE. NP+NJ .AND. NJ .NE. NP+NQ) GO TO 406
      BETA1(NP,NQ,NJ) = PIBY2
      BETA2(NP,NQ,NJ) = PIBY2
  406 CONTINUE
C
C     ZERO LINEAR COEFFICIENT ARRAYS.
      DO 20 KC = 1, 3
      DO 20 NJ = 1, MAXMD2
      DO 20 NP = 1, MAXMD2
      CP(KC,NJ,NP) = 0.0
   20 CONTINUE
C
C     ZERO NONLINEAR COEFFICIENT ARRAY.
      DO 30 KC = 1, 4
      DO 30 NJ = 1, MAXMD2
      DO 30 NPQ = 1, MAXMDD
      D(KC,NJ,NPQ) = 0.0
   30 CONTINUE
C
C     INPUT OF LINEAR COEFFICIENTS.
      DO 40 KC = 1, 3
      READ (9,5003) KMAX
      IF (NOUTCF .GT. 0) WRITE (6,6004) KC, KMAX
      IF (KMAX .EQ. 0)  GO TO 40
      DO 45 K = 1, KMAX
      READ (9,5004) NJ, NP, CP(KC,NJ,NP)
      IF (NOUTCF .GT. 0) WRITE (6,6005) KC, NJ, NP, CP(KC,NJ,NP)
   45 CONTINUE
   40 CONTINUE
C
      DO 305 KC = 4, 5
      READ (9,5003) KMAX
      KCMIN3 = KC - 3
      IF (NOUTCF .GT. 0) WRITE (6,6031) KCMIN3, KMAX
      IF (KMAX .EQ. 0) GO TO 305
      DO 310 K = 1, KMAX
      READ (9,5004) NJ, NP, E(NJ,NP,KCMIN3)
      IF (NOUTCF .GT. 0) WRITE (6,6032) NJ, NP, KCMIN3, E(NJ,NP,KCMIN3)
  310 CONTINUE
  305 CONTINUE
```

```
C
C     INPUT OF NONLINEAR COEFFICIENTS.
      READ (9,5003) NLMAX
      IF (NOUTCF .EQ. 2)  WRITE (6,6006) NLMAX
      IF (NLMAX .EQ. 0)   GO TO 50
      DO 52 NJ = 1, MAXMD2
      KPQMAX(NJ) = 0
   52 CONTINUE
      DO 55 K = 1, NLMAX
      READ (9,5005)   NJ, NP, NQ, DT
      IF (NOUTCF .EQ. 2)  WRITE (6,6007)  NJ, NP, NQ, DT
      KPQMAX(NJ) = KPQMAX(NJ) + 1
      KPQ = KPQMAX(NJ)
      IDP(NJ,KPQ) = NP
      IDQ(NJ,KPQ) = NQ
      NJ12 = (NJ+1)/2
      NP12 = (NP+1)/2
      NQ12 = (NQ+1)/2
      DT = DT * 0.5 * FRQ1(NQ) / (FRQ1(NJ) * PI)
      D(1,NJ,KPQ) = DT * BETA2(NJ12,NP12,NQ12)
      D(2,NJ,KPQ) = - DT * BETA1(NP12,NQ12,NJ12)
      D(3,NJ,KPQ) = DT * BETA2(NQ12,NP12,NJ12)
      D(4,NJ,KPQ) = - DT * BETA2(NP12,NQ12,NJ12)
   55 CONTINUE
   50 CONTINUE
C
C     ************* PRESSURE COEFFICIENT SECTION ***********************
C
C     CALCULATE SPATIAL COORDINATES FOR PRESSURE COMPUTATION.
      Z(1) = 0.0
      Z(2) = ZE
      Z(3) = 0.5 * ZE
C
C     CALCULATE COEFFICIENTS FOR PRESSURE TIME HISTORIES.
      DO 53 NPRES = 1, 3
      DO 53 J = 1, JMX
      NP = (2 * J) - 1
      Z1 = Z(NPRES)
      CALL PHICFS(J,Z1,C1,C3)
      CFT(NPRES,NP) = REAL(C1)
      CFT(NPRES,NP+1) = -AIMAG(C1)
      CFZ(NPRES,NP) = REAL(C3)
      CFZ(NPRES,NP+1) = -AIMAG(C3)
   53 CONTINUE
C
C     OUTPUT OF COEFFICIENTS FOR PRESSURE TIME HISTORIES.
      WRITE (6,6020)
      DO 56 NPRES = 1, 3
      WRITE (6,6014)
      DO 56 J = 1, NJMAX
      WRITE (6,6021) J, Z(NPRES), CFT(NPRES,J), CFZ(NPRES,J)
   56 CONTINUE
```

```
C
C     ************* DATA INPUT SECTION ***********************************
C
      READ (5,5000) TITLE
C
C     ZERO INITIAL VALUE AND FREQUENCY ARRAYS.
    5 DO 57 K = 1, NJMAX
      AS(K) = 0.0
      AC(K) = 0.0
   57 CONTINUE
C
C
C     READ COMBUSTION AND CONTROL PARAMETERS.
      READ (5,5006) H, TSTART, TQUIT, FREQ, BCOMB
      IF (EOF(5)) 300, 1
    1 CONTINUE
      READ (5,5013) A2PARA, B2PARA, EN, OMEGA
      WRITE (6,6034) A2PARA, B2PARA, EN, OMEGA
      DO 46 K = 1, JMX
      OMEGAK = OMEGA * K
      CALL RESPNS(EN,A2PARA,B2PARA,OMEGAK,CRES)
      RES(K) = CRES
      WRITE (6,6035) K, RES(K)
   46 CONTINUE
C
C     READ CONTROL NUMBERS.
      READ (5,5008)  NLOC, NTERMS, NOUT, NCOMB
      IF (NOUT .GT. 0)  NPT = 1
      IF (NCOMB .EQ. 0) WRITE (6,6039)
      IF (NCOMB .EQ. 1) WRITE (6,6040) BCOMB
      WRITE (6,6041)
C
C
      IF (NOUT .EQ. 0)  GO TO 9
C     READ DATA FOR SETTING UP PLOTS.
      READ (5,5009) YHI, YLAB, ITICY
      READ (5,5014) MDPLOT
      MDPLTL = 0
      DO 320 K = 1, JMX
  320 MDPLTL = MDPLTL + MDPLOT(K)
      IF (MDPLTL .EQ. 0) GO TO 9
      READ (5,5015) YHIMD, YLABMD, ITICMD
      YLOMD = - YHIMD
C
C     ************ INITIAL AMPLITUDES SECTION **************************
C
    9 DO 54 K = 1, NTERMS
C
C     INPUT INITIAL AMPLITUDES FOR F-FUNCTIONS.
      READ (5,5007)  J, AST, ACT
      NJ = (2 * J) - 1
      AS(NJ) = AST
      AC(NJ) = ACT
```

```
C
C     CALCULATE INITIAL AMPLITUDES FOR G-FUNCTIONS.
C
      IF (FRQ1(NJ)) 58, 58, 581
  581 GYRU = GAMMA*YR(NJ)*UE
      GYIF = GAMMA*YI(NJ)*FRQ1(NJ)
      GYRF = GAMMA*YR(NJ)*FRQ1(NJ)
      GYIU = GAMMA*YI(NJ)*UE
C
      NPRES = 2
C
      A1 = (1.0 + GYRU)*CFZ(NPRES,NJ+1)
     1     - GYIF*CFT(NPRES,NJ+1)
      A2 = GYRF*CFT(NPRES,NJ+1) + GYIU*CFZ(NPRESVNJ+1)
      A3 = -(1.0 + GYRU)*CFZ(NPRES,NJ) + GYIF*CFT(NPRES,NJ)
      A4 = GYRF*CFT(NPRES,NJ) + GYIU*CFZ(NPRES,NJ)
C
      DET = A1*A1 + A2*A2
      IF (DET .LT. 0.0000001) GO TO 583
      R1 = A3*AC(NJ) - A4*AS(NJ)
      R2 = -A4*AC(NJ) - A3*AS(NJ)
C
      AC(NJ+1) = (R1*A1 + R2*A2)/DET
      AS(NJ+1) = -(R2*A1 - R1*A2)/DET
      GO TO 58
  583 AC(NJ+1) = -AS(NJ)
      AS(NJ+1) = AC(NJ)
C
   58 CONTINUE
   54 CONTINUE
C
C
C     OUTPUT OF INITIAL AMPLITUDES.
      WRITE (6,6016)
      DO 590 J = 1, NJMAX
      IF (AS(J))  591, 592, 591
  592 IF (AC(J))  591, 590, 591
  591 WRITE (6,6017) J, FRQ1(J), AC(J), AS(J)
  590 CONTINUE
      IF (NOUT .GE. 1)  WRITE (6,6027)
C
C     ************* LINEAR COEFFICIENTS SECTION ***********************
C
      DO 59 KC = 1, 2
      DO 59 NJ = 1, MAXMD4
      KPMAX(KC,NJ) = 0
   59 CONTINUE
C
      DO 315 KC = 1, 2
      DO 315 NJ = 1, MAXMD4
      DO 315 NP = 1, MAXMD2
      C(KC,NJ,NP) = 0.0
  315 CONTINUE
```

```
C
C     COMPUTE LINEAR COEFFICIENTS FOR GIVEN VALUES OF
C     HC AND RESPONSE FUNCTION.
  605 DO 60 NJ = 1, NJMAX
      NJ12 = (NJ+1)/2
      DO 60 NP = 1, NJMAX
      NP12 = (NP+1)/2
      FR2K2 = FRQ1(NP)**2 + PARTKL**2
      RESR = REAL(RES(NP12))
      RESI = AIMAG(RES(NP12))
      CT = - 0.5 * FRQ1(NP) / FRQ1(NJ) * DELTA(NJ12,NP12) * (CP(2,NJ,NP)
     1      + HC * RESR * E(NJ,NP,1) + HC * RESI * E(NJ,NP,2)
     2      - CP(3,NJ,NP)/FR2K2)
      IF (CT) 61, 62, 61
   61 KPMAX(1,NJ) = KPMAX(1,NJ) + 1
      KP = KPMAX(1,NJ)
      IC(1,NJ,KP) = NP
      C(1,NJ,KP) = CT
   62 CONTINUE
      CT = - 0.5 / FRQ1(NJ) * DELTA(NJ12,NP12) * (CP(1,NJ,NP)
     1      + PARTKL * CP(3,NJ,NP)/FR2K2)
      IF (NJ .EQ. NP) CT = CT + FRQ1(NJ) * 0.5
      IF(CT) 63, 64, 63
   63 KPMAX(2,NJ) = KPMAX(2,NJ) + 1
      KP = KPMAX(2,NJ)
      IC(2,NJ,KP) = NP
      C(2,NJ,KP) = CT
   64 CONTINUE
      CT = 0.5/FRQ1(NJ) * DELTA(NJ12,NP12) * (CP(1,NJ,NP) +
     1      PARTKL * CP(3,NJ,NP) / FR2K2)
      IF (NJ .EQ. NP) CT = CT - 0.5 * FRQ1(NJ)
      IF (CT) 420, 422, 420
  420 KPMAX(1,NJ+NJMAX) = KPMAX(1,NJ+NJMAX) + 1
      KP = KPMAX(1,NJ+NJMAX)
      IC(1,NJ+NJMAX,KP) = NP
      C(1,NJ+NJMAX,KP) = CT
  422 CONTINUE
      CT = - 0.5 * FRQ1(NP) / FRQ1(NJ) * DELTA(NJ12,NP12) *
     1      (CP(2,NJ,NP) + HC * RESR * E(NJ,NP,1) + HC * RESI *
     2      E(NJ,NP,2) - CP(3,NJ,NP) / FR2K2)
      IF (CT) 424, 410, 424
  424 KPMAX(2,NJ+NJMAX) = KPMAX(2,NJ+NJMAX) + 1
      KP = KPMAX(2,NJ+NJMAX)
      IC(2,NJ+NJMAX,KP) = NP
      C(2,NJ+NJMAX,KP) = CT
  410 CONTINUE
   60 CONTINUE
C
```

```
C     ************** INITIAL VALUES SECTION *****************************
C
      NSTEP = 0
      NP1 = 3
      H6 = H/6
      TIME = 0.0
      I = NP1
      TI(I) = TIME
C
      DO 75 J = 1, NJMAX
      JP = J + NJMAX
      U(I,J) = AS(J)
      U(I,JP) = AC(J)
   75 CONTINUE
C     CALCULATE INITIAL VALUES OF PRESSURE AND VELOCITY.
      DO 704 NPRES = 1, 3
      DO 702 J = 1, NJMAX
      COEF(1,J) = CFT(NPRES,J)
      COEF(2,J) = CFZ(NPRES,J)
      ARG = FRQ1(J) * TIME
      SINARG = SIN(ARG)
      COSARG = COS(ARG)
      UMA(J) = U(I,J) * SINARG + U(I,J+NJMAX) * COSARG
      UMA(J+NJMAX) = FRQ1(J) * (U(I,J) * COSARG - U(I,J+NJMAX) * SINARG)
  702 CONTINUE
      DO 703 J = 1, NU
      Y(J) = U(I,J)
  703 CONTINUE
      UBAR = UE * Z(NPRES)
      UMS = UE
      CALL PRSVEL(UBAR,UMS,UMA,P,VZGAS,VZPAR)
      PRESS(NPRES) = P
  704 CONTINUE
      PRS(I) = PRESS(NLOC)
   70 CONTINUE
C
      IF (NHISTR .EQ. 0) WRITE (6,6008) GAMMA, UE
      IF (NHISTR .EQ. 0) WRITE (6,6022)
C
C     ************** INITIALIZE CONTROL NUMBERS **************************
C
      LINE = 8
      K = 0
      MAXNO = 0
      MAXP = 0
      IF (NOUT .EQ. 0)  GO TO 100
      JPLOT = 0
      TMIN = TSTART
      TMAX = TSTART + TDEL
      YLO = -YHI
C
```

```
C     ************** NUMERICAL CALCULATIONS SECTION **********************
C
  100 I = NP1
C
C     RUNGE-KUTTA INTEGRATION SCHEME.
  105 NSTEP = (I - NP1 + (LAST - NP1) * K)
      RSTEP = NSTEP
      TIME = RSTEP * H
      TI(I) = TIME
      DO 120 J = 1, NU
      Y(J) = U(I,J)
  120 CONTINUE
      CALL RHS(Y,YP)
      DO 130 J = 1, NU
      FZ(1,J) = YP(J)
  130 CONTINUE
      DO 140 II = 2,4
      DO 144 J = 1, NU
      UZ(J) = Y(J) + AA(II) * H * FZ(II-1,J)
  144 CONTINUE
      CALL RHS(UZ,YP)
      DO 148 J = 1, NU
      FZ(II,J) = YP(J)
  148 CONTINUE
  140 CONTINUE
      DO 150 J = 1, NU
      U(I+1,J) = Y(J) + (FZ(1,J)+2.0*(FZ(2,J)+FZ(3,J)) + FZ(4,J)) * H6
  150 CONTINUE
C
C     CALCULATE PRESSURE TIME HISTORIES.
      DO 154 NPRES = 1, 3
      DO 152 J = 1, NJMAX
      COEF(1,J) = CFT(NPRES,J)
      COEF(2,J) = CFZ(NPRES,J)
      ARG = FRQ1(J) * TIME
      SINARG = SIN(ARG)
      COSARG = COS(ARG)
      UMA(J) = U(I,J) * SINARG + U(I,J+NJMAX) * COSARG
      UMA(J+NJMAX) = FRQ1(J) * (U(I,J)*COSARG - U(I,J+NJMAX)*SINARG)
  152 CONTINUE
      UBAR = UE * Z(NPRES)
      UMS = UE
      CALL PRSVEL(UBAR,UMS,UMA,P,VZGAS,VZPAR)
      PRESS(NPRES) = P
  154 CONTINUE
      PRS(I) = PRESS(NLOC)
      IF (K .EQ. 0) GO TO 175
C
C     DETERMINE MAXIMUM AND MINIMUM PRESSURE AT LOCATION SPECIFIED
C     BY NLOC.
      DPL = PRS(I) - PRS(I-1)
      DPS = PRS(I-1) - PRS(I-2)
      IF (DPL*DPS) 173, 173, 175
```

AD-A045 118 GEORGIA INST OF TECH ATLANTA SCHOOL OF AEROSPACE ENG--ETC F/G 21/8.2
APPROXIMATE NONLINEAR ANALYSIS OF SOLID ROCKET MOTORS AND T-BUR--ETC(U)
JUL 77 E A POWELL, M S PADMANABHAN, B T ZINN F04611-75-C-0036
UNCLASSIFIED AFRPL-TR-77-48-VOL-2 NL

3 OF 4
AD
A045 118

```
173 PNUM = PRS(I-2) - PRS(I)
    PDEN = 2.0 * (PRS(I-2) + PRS(I) - 2.0*PRS(I-1))
    IF (PDEN) 174, 175, 174
174 PP = PNUM/PDEN
    PA = (PP - 1.0) * PP * 0.5
    PB = 1.0 - (PP * PP)
    PC = (PP + 1.0) * PP * 0.5
    MAXP = MAXP + 1
    PMAX(MAXP) = PA*PRS(I-2) + PB*PRS(I-1) + PC*PRS(I)
    TIMAX(MAXP) = TI(I-1) + PP*H
    IF (MAXP .GE. 500)  GO TO 250
175 CONTINUE
C
    IF (TIME .LT. TSTART)  GO TO 155
    IF (NOUT .EQ. 0) GO TO 156
C
C   ************* TIME HISTORY PLOTTING SECTION ********************
C
    IF (TMAX .GT. TQUIT)  GO TO 156
    IF ((TIME .GT. TMAX) .OR. (JPLOT .GE. 500))  GO TO 1000
C
    JPLOT = JPLOT + 1
C
C   FILL TIME ARRAY FOR PLOTTING.
    TPLOT(JPLOT) = TIME
C
C   FILL PRESSURE ARRAYS FOR PLOTTING.
    DO 1001 J = 1,3
    YPLOT(J,JPLOT) = PRESS(J)
1001 CONTINUE
C
C
    IF (MDPLTL .EQ. 0) GO TO 156
C   FILL MODE AMPLITUDE ARRAYS FOR PLOTTING.
    DO 322 J = 1, JMX
    IF (MDPLOT(J) .EQ. 0) GO TO 322
    J12 = 2*J - 1
    UPLOT(J,JPLOT) = U(I,J12)
322 CONTINUE
C
    GO TO 156
C
1000 NUM = JPLOT
C
C   PLOT TIME HISTORIES.
C
    DO 1020 NPLOT = 1, NOUT
C
    JPLOT = 0
C
```

```
C     ASSIGN PLOTTING PARAMETERS.
      YMIN = YLO
      YMAX = YHI
      NTICY = ITICY
      DELY = YLAB
C
C     ELIMINATE POINTS THAT ARE OUT OF THE ORDINATE RANGE.
      DO 1010 J = 1, NUM
      IF ((YPLOT(NPLOT,J) .LT. YMIN) .OR. (YPLOT(NPLOT,J) .GT. YMAX))
     1   GO TO 1010
      JPLOT = JPLOT + 1
      DUMMYT(JPLOT) = TPLOT(J)
      DUMMYY(JPLOT) = YPLOT(NPLOT,J)
 1010 CONTINUE
C
      IF (JPLOT .EQ. 0)  GO TO 1020
      GO TO (1011,1014,1015), NPLOT
C
C     PLOT HEAD-END PRESSURE.
 1011 CALL GRAPHS(IBUF,512,4,JPLOT,11,NTICY,TMAX,YMAX,TMIN,YMIN,
     1              ITT,ITY1,21,30,DUMMYT,DUMMYY,2.0,DELY,TITLE)
      GO TO 1020
C
C     PLOT NOZZLE PRESSURE.
 1014 CALL GRAPHS(IBUF,512,4,JPLOT,11,NTICY,TMAX,YMAX,TMIN,YMIN,
     1              ITT,ITY2,21,28,DUMMYT,DUMMYY,2.0,DELY,TITLE)
      GO TO 1020
C
C     PLOT PRESSURE AT THE CENTER (X = 0.5).
 1015 CALL GRAPHS(IBUF,512,4,JPLOT,11,NTICY,TMAX,YMAX,TMIN,YMIN,
     1              ITT,ITY3,21,35,DUMMYT,DUMMYY,2.0,DELY,TITLE)
C
 1020 CONTINUE
C
      DO 324 NPLOT = 1, JMX
      IF (MDPLOT(NPLOT) .EQ. 0) GO TO 324
      JPLOT = 0
      DO 328 J123 = 1, 2
      IF (NPLOT .EQ. 1) MTITL(J123) = MTITL1(J123)
      IF (NPLOT .EQ. 2) MTITL(J123) = MTITL2(J123)
      IF (NPLOT .EQ. 3) MTITL(J123) = MTITL3(J123)
      IF (NPLOT .EQ. 4) MTITL(J123) = MTITL4(J123)
      IF (NPLOT .EQ. 5) MTITL(J123) = MTITL5(J123)
      IF (NPLOT .EQ. 6) MTITL(J123) = MTITL6(J123)
  328 CONTINUE
      DO 326 J = 1, NUM
      IF ((UPLOT(NPLOT,J) .LT. YLOMD) .OR. (UPLOT(NPLOT,J)
     1        .GT. YHIMD)) GO TO 326
      JPLOT = JPLOT + 1
      DUMMYT(JPLOT) = TPLOT(J)
      DUMMYY(JPLOT) = UPLOT(NPLOT,J)
  326 CONTINUE
```

```
      IF (JPLOT .EQ. 0) GO TO 324
      CALL GRAPHS(IBUF, 512, 4, JPLOT, 11, ITICMD, TMAX, YHIMD, TMIN,
     1     YLOMD, ITT, MTITL, 21, 20, DUMMYT, DUMMYY, 2.0, YLABMD, TITLE)
  324 CONTINUE
C
C     REASSIGN PLOTTING PARAMETERS FOR NEXT SET OF PLOTS.
      JPLOT = 0
      TMIN = TMAX
      TMAX = TMAX + TDEL
C
C     ************* TIME HISTORY PRINTED OUTPUT SECTION ****************
C
  156 IF (NHISTR .EQ. 0)
     1     WRITE (6,6011) NSTEP, TIME, (PRESS(J), J = 1,3), VZGAS, VZPAR
      LINE = LINE + 1
  157 IF (TIME .GT. TQUIT)  GO TO 250
      IF (LINE .LT. 52)  GO TO 155
      IF (NHISTR .EQ. 0) WRITE (6,6013)
      IF (NHISTR .EQ. 0) WRITE (6,6022)
      LINE = 4
C
  155 I = I + 1
      IF (I .LT. LAST)  GO TO 105
      K = K + 1
C
C     RE-ASSIGN ARRAYS.
      DO 200 I = 1, NP1
      ILAST = LAST - NP1 + I
      PRS(I) = PRS(ILAST)
      TI(I) = TI(ILAST)
      DO 200 J = 1, NU
      U(I,J) = U(ILAST,J)
  200 CONTINUE
      GO TO 100
C
C
C     ************* PRESSURE MAXIMA AND MINIMA PRINTOUT ****************
C
  250 WRITE (6,6023) Z(NLOC), MAXP
      LINE = 4
      DO 255 JST = 1, MAXP, 8
      JSTART = JST
      JSTOP = JST + 7
      IF (JSTOP .GT. MAXP) JSTOP = MAXP
      WRITE (6,6024) (PMAX(J), J = JSTART, JSTOP)
      WRITE (6,6024) (TIMAX(J), J = JSTART, JSTOP)
      WRITE (6,6014)
      LINE = LINE + 3
      IF (LINE .LT. 52)  GO TO 255
      LINE = 0
      WRITE (6,6013)
  255 CONTINUE
```

```
      CALL GROWTH(MAXP,TIMAX,PMAX,FREQ)
      GO TO 5
  300 CONTINUE
C     TURN OFF PLOTTING ROUTINE.
      IF (NPT .EQ. 1)  CALL PLOT(0.0,0.0,999)
C
C     ************** READ FORMAT SPECIFICATIONS ***************************
C
 5000 FORMAT (7A10)
 5001 FORMAT (3F10.0,3I5)
 5002 FORMAT (2I5,1X,A4)
 5003 FORMAT (2I5)
 5004 FORMAT (2I5,F15.8)
 5005 FORMAT (3I5,F15.8)
 5006 FORMAT (7F10.0)
 5007 FORMAT (I5,2F10.0)
 5008 FORMAT (6I5)
 5009 FORMAT (2F10.0,I5)
 5010 FORMAT (I5,4F12.8)
 5011 FORMAT (7F15.8)
 5013 FORMAT (4F10.0)
 5014 FORMAT (6I5)
 5015 FORMAT (2F10.0,I5)
C
C     ************** WRITE FORMAT SPECIFICATIONS *************************
C
 6001 FORMAT (1H1,//,6X,4HUE =,F6.4,//,6X,17HNUMBER OF MODES =,
     1        I2,//,6X,7HGAMMA =,F5.2)
 6002 FORMAT (//////,6X,14HNAME     J    L/)
 6003 FORMAT (6X,A4,2I5)
 6004 FORMAT (1H0,26H NUMBER OF COEFFICIENTS C(,I1,10H,NJ,NP) IS,I5/)
 6005 FORMAT (2X,2HC(,I1,1H,,I2,1H,,I2,4H) = ,F10.5)
 6006 FORMAT (1H0,38H NUMBER OF COEFFICIENTS D(NJ,NP,NQ) IS,I5/)
 6007 FORMAT (2X,2HD(,I2,1H,,I2,1H,,I2,4H) = ,F10.5)
 6008 FORMAT (1H1,2X,17HMOTOR PARAMETERS;,15X,
     1        8HGAMMA = ,F4.2,10X,19HEXIT MACH NUMBER = ,F7.5//)
 6009 FORMAT (/,6X,10HGAMMABAR =,F9.6,//)
 6010 FORMAT (1H0,////,6X,1HJ,7X,2HYR,8X,2HYI,7X,3HEPS,7X,3HETA//)
 6011 FORMAT (2X,I5,F12.5,5F22.5)
 6013 FORMAT (1H1)
 6014 FORMAT (1H )
 6015 FORMAT (2X,I5,4F10.5)
 6016 FORMAT (1H1,///,1X,36H INITIAL CONDITIONS ARE OF THE FORM://
     1        2X,47HU(I,J) =   AC(J)*COS(FREQ*T) + AS(J)*SIN(FREQ*T),
     2        ////6X,1HJ,6X,9HFREQUENCY,10X,5HAC(J),10X,5HAS(J)//)
 6017 FORMAT (2X,I5,4F15.8/)
 6020 FORMAT (1H1,/,2X,45HCOEFFICIENTS FOR COMPUTATION OF WALL PRESSURE,
     1        10H WAVEFORMS////34X,27HCOEFFICIENTS IN SERIES FOR://
     2        37X,4HTIME,21X,5HAXIAL/6X,1HJ,7X,1HZ,19X,10HDERIVATIVE,
     3        15X,10HDERIVATIVE//)
 6021 FORMAT (2X,I5,F10.3,12X,F15.7,10X,F15.7)
```

```
6022 FORMAT (3X,4HSTEP,8X,4HTIME,15X,8HPRESSURE,14X,8HPRESSURE,14X,
    1          8HPRESSURE,14X,7HGAS VEL,15X,7HPAR VEL,/,34X,
    2          8HAT Z=0.0,14X,8HAT Z=1.0,14X,8HAT Z=0.5,13X,
    3          8HAT Z=0.5,14X,8HAT Z=0.5//)
6023 FORMAT (1H1,38H PRESSURE MAXIMA AND MINIMA AT:     Z = ,F5.2,
    1          /19H VALUES COMPUTED:  ,I3//)
6024 FORMAT (1H ,7X,8F13.6)
6027 FORMAT (2X//2X,33HTHIS RUN PRODUCES PLOTTED OUTPUT.)
6030 FORMAT (///,6X,27HPARTICLE DIA (IN MICRONS) = ,F5.1,10X,
    1          4HCM =,F4.2,10X,18HFREQ (IN HERTZ) = ,F6.1,//,
    2          6X,26HCHAMBER TEMP (IN DEG K) = ,F6.1,10X,4HSP =,
    3          F4.2,10X,27HRHOM (IN KG/CUBIC METER) = ,F6.1,//,6X,
    4          27HPARTICLE DRAG CONSTANT, K =,F8.4,////)
6031 FORMAT (1H0,32H NUMBER OF COEFFICIENTS E(NJ,NP,,,I1,4H) IS,I5/)
6032 FORMAT (2X,2HE(,I2,1H,,I2,1H,,I1,4H) = ,F10.5)
6033 FORMAT (/////,6X,26HPARTICLES ARE NOT PRESENT.//)
6034 FORMAT (1H1,///,3X,22HCOMBUSTION PARAMETERS:,5X,3HA =,F6.3,6X,
    1          3HB =,F5.3,5X,4HEN =,F5.3,5X,7HOMEGA =,F6.3,
    2          //////,25X,1HJ,16X,4HRESR,15X,4HRESI,//)
6035 FORMAT (1H0,20X,I5,10X,F10.4,9X,F10.4)
6039 FORMAT (///,3X,27HLINEAR COMBUSTION RESPONSE.)
6040 FORMAT (///,3X,30HNONLINEAR COMBUSTION RESPONSE:,5X,
    1          8HBCOMB = ,F6.3)
6041 FORMAT (/////,3X,24HLINEAR PARTICLE DAMPING.)
     END
```

```
      SUBROUTINE PRSVEL(UBAR,UMS,UMA,P,VZGAS,VZPAR)
C
C     THIS SUBROUTINE COMPUTES THE PRESSURE AND VELOCITY.
C
C     UBAR IS THE LOCAL AXIAL STEADY STATE MACH NUMBER.
C     UMS IS THE DERIVATIVE OF THE MACH NUMBER.
C     UMA IS THE ARRAY CONTAINING VALUES OF THE MODE-AMPLITUDE
C     FUNCTIONS AND THEIR DERIVATIVES.
C     P IS THE VALUE OF THE PRESSURE PERTURBATION.
C     VZGAS IS THE AXIAL COMPONENT OF GAS VELOCITY.
C     VZPAR IS THE AXIAL COMPONENT OF PARTICLE VELOCITY.
C
C
      DIMENSION      UMA(24), SUM(5), SUMSQ(2)
      COMMON         /BLK3/    NPRTKL, NJMAX, NLMAX, GAMMA, COEF(2,12)
      COMMON         /BLK4/    PARTKL, RHOP, FRQ1(12)
C
      DO 10 I = 1, 5
      SUM(I) = 0.0
   10 CONTINUE
C
      DO 20 J = 1, NJMAX
      JY = J + NJMAX
   20 SUM(1) = SUM(1) + UMA(JY) * COEF(1,J)
      DO 50 J = 1, NJMAX
      SUM(2) = SUM(2) + UMA(J) * COEF(2,J)
      SUM(3) = SUM(3) + UMA(J) * COEF(1,J)
      IF (NPRTKL .EQ. 0) GO TO 50
      SUM(4) = SUM(4) + COEF(1,J) * (PARTKL * UMA(J) -
     1         UMA(J+NJMAX)) / (FRQ1(J)**2 + PARTKL**2)
      SUM(5) = SUM(5) + COEF(2,J) * (PARTKL * UMA(J) - UMA(J+NJMAX))
     1         / (FRQ1(J)**2 + PARTKL**2)
   50 CONTINUE
      PLIN = SUM(1) + UBAR * SUM(2) + UMS * SUM(3)
     1       + PARTKL * RHOP * (SUM(3) - PARTKL * SUM(4))
      PNL = 0.0
      IF (NLMAX .EQ. 0)  GO TO 40
      DO 30 I = 1, 2
      SUMSQ(I) = SUM(I) * SUM(I)
   30 CONTINUE
      PNL = 0.5 * (SUMSQ(2) - SUMSQ(1))
C
   40 P = -GAMMA * (PLIN + PNL)
      VZGAS = SUM(2)
      VZPAR = PARTKL * SUM(5)
C
      RETURN
      END
```

```
      SUBROUTINE RHS(U,UP)
C
C
      COMPLEX        RES(6), RESNL(6)
      DIMENSION      U(24), UP(24), E(12,12,2)
      COMMON         C(2,24,12), D(4,12,144), KPMAX(2,24), IC(2,24,12),
     1               KPQMAX(12), IDP(12,144), IDQ(12,144)
      COMMON         /BLK3/     NPRTKL, NJMAX, NLMAX, GAMMA, COEF(2,12)
      COMMON         /BLK4/     PARTKL, RHOP, FRQ1(12)
      COMMON         /BLK5/     RES, NCOMB, BCOMB, E
C
      IF (NCOMB .EQ. 0) GO TO 116
      JMX = NJMAX/2
      DO 118 NJ = 1, JMX
      NJPLNJ = 2*NJ
      NJ2MN1 = NJPLNJ - 1
      RESNL(NJ) = RES(NJ) * BCOMB * SQRT (UP(NJ2MN1)**2+UP(NJPLNJ)**2)
  118 CONTINUE
  116 CONTINUE
C
      DO 10 NJ = 1, NJMAX
      NJP = NJ + NJMAX
      SL1 = 0.0
      SL2 = 0.0
      SNL1 = 0.0
      SNL2 = 0.0
      SNLC = 0.0
      MAX = KPMAX(1,NJ)
      IF (MAX .EQ. 0) GO TO 25
      DO 20 KP = 1, MAX
      NP = IC(1,NJ,KP)
      SL1 = SL1 + (C(1,NJ,KP) * U(NP))
   20 CONTINUE
   25 MAX = KPMAX(2,NJ)
      IF (MAX .EQ. 0) GO TO 45
      DO 30 KP = 1, MAX
      NP = IC(2,NJ,KP)
      SL2 = SL2 + (C(2,NJ,KP) * U(NP+NJMAX))
   30 CONTINUE
   45 IF (NLMAX .EQ. 0)  GO TO 55
      MAX = KPQMAX(NJ)
      IF (MAX .EQ. 0) GO TO 55
      DO 50 KPQ = 1, MAX
      NP = IDP(NJ,KPQ)
      NQ = IDQ(NJ,KPQ)
      SNL1 = SNL1 + D(1,NJ,KPQ) * U(NP) * U(NQ+NJMAX) +
     1       D(2,NJ,KPQ) * U(NQ) * U(NP+NJMAX)
      SNL2 = SNL2 + D(3,NJ,KPQ) * U(NP) * U(NQ) +
     1       D(4,NJ,KPQ) * U(NP+NJMAX) * U(NQ+NJMAX)
   50 CONTINUE
```

```
55 UP(NJ) = SL1 + SL2 + SNL1
   SL1 = 0.0
   SL2 = 0.0
   MAX = KPMAX(1,NJP)
   IF (MAX .EQ. 0) GO TO 65
   DO 60 KP = 1, MAX
   NP = IC(1,NJP,KP)
   SL1 = SL1 + C(1,NJP,KP) * U(NP)
60 CONTINUE
65 MAX = KPMAX(2,NJP)
   IF (MAX .EQ. 0) GO TO 75
   DO 70 KP = 1, MAX
   NP = IC(2,NJP,KP)
   SL2 = SL2 + C(2,NJP,KP) * U(NP+NJMAX)
70 CONTINUE
75 UP(NJP) = SL1 + SL2 + SNL2
10 CONTINUE
   RETURN
   END
```

4. APPROXIMATE T-BURNER PROGRAMS

This chapter describes the programs which determine the T-burner stability characteristics, TB1 and TB2. TB1 and TB2 perform the same tasks for T-burners as SOLID1 and SOLID2 perform for rocket motors. The programs TB1 and TB2 have the same structure as programs SOLID1 and SOLID2, and many subroutines are common between these sets of programs. Hence, the ensuing discussion of programs TB1 and TB2 is kept brief, and wherever possible one is referred to the discussion on programs SOLID1 and SOLID2.

4.1 PROGRAM TB1

Program TB1 calculates the coefficients of both the linear and nonlinear terms which appear in the T-burner mode-amplitude equations. The coefficients to be calculated are functions of various integrals of trigonometric functions (Appendix C).

Program structure. The structure of this program is similar to that of SOLID1. It can be divided functionally into five sections: (1) input, (2) calculation of the linear coefficients, (3) calculation of the nonlinear coefficients, (4) obtaining the coefficients of the equivalent uncoupled real system, and (5) output.

The inputs to the program include the description of the T-burner geometry (length of the propellant grain, width of the vent, ratio of radius to burner length, effective vent plug-flow length), velocity at the burning surface, information about the modes included in the approximating series, particle characteristics and various control numbers. As in the case of the motor, all the inputs are supplied to the main program.

As explained in Volume I, the axial acoustic eigenvalues for the T-burner are those for a cylinder with hard walls at both ends. In other words, the eigenvalue for the n^{th} axial mode is simply $n\pi$ and the eigenfunctions are real numbers. Hence, program TB1 does not include subroutines EIGVAL and FCNS which were present for program SOLID1. The integrals of the products of two axial eigenfunctions and the steady-state quantities are computed by means of subroutines AXIAL1 and STEADY. The linear coefficients are then calculated and normalized by dividing by the coefficient of the highest derivative (i.e., $C_o(j,j)$).

In the third section, the integrals of products of three axial eigenfunctions are computed using the subroutine AXIAL2 and the complex nonlinear coefficients are calculated.

The remaining two sections are the same as in SOLID1.

Description of Input. The input deck for Program TB1 is the same as for Program SOLID1, except the second and third cards which give information about burner geometry and vent effect as described below. Furthermore, the nozzle admittance data card is absent from the data deck. A complete list of inputs is given below.

The first card gives the title of the case.

Second card: GAM, BETA, BETAV, RRL, UB, VL, EL

GAM is the specific heat ratio.

BETA is the ratio of the length of the two cup grains to the length of the T-burner.

BETAV is the ratio of the vent width to the length of the burner.

RRL is the radius-to-length ratio.

UB is the velocity at the burning surface.

VL determines the vent effect:

VL = 0 vent gain.

VL = 1 no effect.

VL = 2 vent loss.

EL is the effective vent length.

Third card: NJMAX, NØNLIN, NEGL, NØUT, NPRTKL, NBURN

NJMAX is the number of mode-amplitude functions in the assumed series solution.

The coefficients computed are determined by NØNLIN as follows:

NØNLIN = 0 linear coefficients only.

NØNLIN = 1 both linear and nonlinear coefficients.

Coefficients to be neglected are determined by NEGL as follows:

NEGL = 0 terms smaller than 0.00001 are neglected.

NEGL = 1 linear terms smaller than SM1 and nonlinear terms smaller than SM2 are neglected.

The output is determined by NØUT as follows:

NØUT = 0 printed output only.

NØUT = 1 write into a file and print output.

NØUT = 2 write into a file only.

NPRTKL determines whether the particles are present:

NPRTKL = 0 particles not present.

NPRTKL = 1 particles present.

NBURN indicates whether end burning is present:

NBURN = 0 not present.

NBURN = 1 present.

Next card (necessary only if NPRTKL = 1): DIA, RHØM, SP, TEMP, FREQ, CM

DIA is the particle diameter, in microns.

RHØM is the density of the particle material, in Kg/m^3.

SP is the ratio of the specific heats of particle material and gas.

TEMP is the chamber temperature, in degrees Kelvin.

FREQ is the frequency of oscillation in pure gas, in Hertz.

CM is the particle loading.

Next card (necessary only if NEGL = 1): SM1, SM2

SM1 and SM2 are as defined above.

Next NJMAX cards: J, L(J), NAME(J)

Each mode-amplitude is assigned an integer J.

The mode is specified by the index L(J).

L(J) is the axial mode number and must not exceed NJMAX.

NAME(J) is a four-character name for the J^{th} mode.

Description of the Subroutines. The different subroutines included in program TB1 are described below:

SUBRØUTINE AXIAL1 (NØPT, NP, NJ, RESULT). This subroutine calculates the different integrals which appear in the expressions for the coefficients of the linear terms in the T-burner amplitude equations. While this subroutine performs the same function for TB1 as its counterpart performs in SOLID1, the two versions of AXIAL1 differ considerably in their details. The T-burner version of AXIAL1 returns the computed value of the desired integral under the name RESULT according to the value of NØPT as follows:

$$\text{NØPT} = 1 \qquad \text{RESULT} = \int_0^1 X_p X_j \, dx$$

$$\text{NØPT} = 2 \qquad \text{RESULT} = \int_0^1 \frac{d^2 X_p}{dx^2} X_j \, dx$$

$$\text{NØPT} = 3 \qquad \text{RESULT} = \int_0^1 \frac{d\bar{u}}{dx} X_p X_j \, dx$$

$$\text{NØPT} = 4 \qquad \text{RESULT} = \int_0^1 \bar{u} \frac{dX_p}{dx} X_j \, dx$$

$$\text{NØPT} = 5 \qquad \text{RESULT} = \int_0^1 \bar{\rho}_p X_p X_j \, dx$$

$$\text{NØPT} = 6 \qquad \text{RESULT} = \int_0^1 \bar{\rho}_p \bar{u}_p \frac{dX_p}{dx} X_j \, dx$$

$$\text{NØPT} = 7 \qquad \text{RESULT} = \int_0^1 \bar{u}_p \frac{dX_p}{dx} X_j \, dx$$

$$\text{NØPT} = 8 \qquad \text{RESULT} = \int_0^1 \frac{d\bar{u}_p}{dx} X_p X_j \, dx$$

$$\text{NØPT} = 9 \qquad \text{RESULT} = \int_0^{\beta/2} \frac{d\bar{u}}{dx} X_p X_j \, dx + \int_{1-\beta/2}^1 \frac{d\bar{u}}{dx} X_p X_j \, dx$$

$$\text{NØPT} = 10 \qquad \text{RESULT} = \int_{(1-\beta_v)/2}^{(1+\beta_v)/2} \frac{d\bar{u}_p}{dx} X_p X_j \, dx$$

$$\text{NØPT} = 11 \qquad \text{RESULT} = \int_{(1-\beta_v)/2}^{(1+\beta_v)/2} \frac{d\bar{u}}{dx} X_p X_j \, dx$$

In the above expressions, X_p and X_j are the axial eigenfunctions for the p^{th} and j^{th} axial mode, with p and j being equal to NP and NJ respectively, and $\bar{u}$ and $\bar{u}_p$ are the local steady-state velocities of the gas and particles respectively. Also $\bar{\rho}_p$ is the local steady-state density of the particles, and β and β_v are the dimensionless propellant cup length and vent width as defined in Volume I.

The required eigenvalues B are obtained from the main program through the blank common; β and β_v are obtained through common block BLK7. The steady-state quantities are obtained from the subroutine STEADY. The integrals for NØPT = 1 and NØPT = 2 are obtained analytically, but for the other cases a numerical integration scheme using Simpson's rule is employed.

<u>SUBRØUTINE AXIAL2 (NØPT, NP, NQ, NJ, RESULT)</u>. This subroutine returns RESULT with the value of the following integrals:

$$\text{NØPT} = 1 \qquad \text{RESULT} = \int_o^1 \frac{dX_p}{dx} \frac{dX_q}{dx} X_j \, dx$$

$$\text{NØPT} = 2 \qquad \text{RESULT} = \int_o^1 \frac{d^2X_p}{dx^2} X_q X_j \, dx$$

where X_p, X_q and X_j are the p^{th}, q^{th} and j^{th} eigenfunctions respectively. Subscripts p(=NP), q(=NQ) and j(=NJ) represent the axial mode numbers. The eigenvalues B are supplied to the subroutine through blank common. All the quantities involved in these integrals are real numbers, the eigenfunctions are trigonometric functions, and the integrals are evaluated in the subroutine analytically.

<u>SUBRØUTINE STEADY (X, UBAR, UPBAR, RHØP, DUBAR, DUPBAR)</u>. This subroutine computes the steady-state flow variables at a specified location X in the T-burner. UBAR and UPBAR are the computed steady-state velocities of the gas phase and particle phase respectively, DUBAR and DUPBAR are their axial derivatives, and RHØP is the steady-state value of the particle density. All of these quantities are calculated according to the steady-state equations given in Section 2.6 of Volume I. Common block BLK7 supplies the information necessary to compute these variables.

<u>SUBRØUTINE GJR (A, NC, NR, N, MC, JC, V)</u>. This subroutine is identical to the one used in Program SOLID1 and described in Section 3.1.

<u>Description of Output</u>. The arrangement of output and the variables controlling the output are the same as for Program SOLID1 as described in Section 3.1. As before, two modes of output - printed output and disk storage - are available and the disk is given the I/O device number 9. The data is written on the disk by setting NØUT = 1 or NØUT = 2, and the data on the disk forms part of the input to Program TB2 to be described in Section 4.2.

Sample Case. The sample case which is considered here refers to a T-burner with radius to length ratio of 0.05071 and a vent whose width is 10% of the total length of the burner. The total length of the propellant grain is 10% of the total length of the burner (5% at either end), γ is 1.23 and the burning velocity at the propellant surface is 0.001978. The particles are 2.5 microns in diameter with a particle loading of 0.36. The pure-gas frequency of oscillation is 1071 Hertz, and the temperature in the T-burner is 3525°K. The first five longitudinal modes are considered, and it is desired to obtain a printed output as well as disk storage of generated data so that they may be used for checking out program TB2 later.

An input deck needed for running program TB1 with the above T-burner conditions is illustrated on the next page. The printed output generated by the program TB1 for this input is shown in the following pages.

```
TEST CASE FØR TB1
      1.23      0.10      0.10   0.05071  0.001978       1.0     0.166
    5    1    0    1    1    1
       2.5    4000.0      0.68    3525.0    1071.0      0.36
    1    1 1L
    2    2 2L
    3    3 3L
    4    4 4L
    5    5 5L
```

TEST CASE FOR TB1

GAMMA = 1.230

BETA = .100

BETAV = .10000

R/L = .05071

UB =-.00198

VL = 1.00

END BURNING IS PRESENT.

PARTICLE DIA (IN MICRONS) = 2.50 CM = .36 FREQ (IN HERTZ) = 1071.0

CHAMBER TEMP (IN DEG K) = 3525.0 SP = .68 RHOM (IN KG/CUBIC METER) = 4000.0

PARTICLE DRAG COEFFICIENT, K = 29.9186

NAME	J	L	B(J)
1L	1	1	3.14159
2L	2	2	6.28319
3L	3	3	9.42478
4L	4	4	12.56637
5L	5	5	15.70796

DECOUPLED COEFFICIENT OF B(P): C(1,J,P)

J \ P	1	2	3	4	5	6	7	8	9	10
1	9.869604	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.000000	9.869604	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
3	0.000000	0.000000	39.478418	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
4	0.000000	0.000000	0.000000	39.478418	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5	0.000000	0.000000	0.000000	0.000000	88.826440	0.000000	0.000000	0.000000	0.000000	0.000000
6	0.000000	0.000000	0.000000	0.000000	0.000000	88.826440	0.000000	0.000000	0.000000	0.000000
7	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	157.913670	0.000000	0.000000	0.000000
8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	157.913670	0.000000	0.000000
9	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	246.740110	0.000000
10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	246.740110

DECOUPLED COEFFICIENT OF B(P): C(1,J,P)

J \ P	11	12	13	14	15	16	17	18	19	20
1	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
3	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
7	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
9	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

DECOUPLED COEFFICIENT OF THE DERIVATIVE OF B(P): C(2,J,P)

J \ P	1	2	3	4	5	6	7	8	9	10
1	10.801283	0.000000	.001194	0.000000	-.016212	0.000000	.001392	0.000000	.012917	0.000000
2	0.000000	10.801283	0.000000	.001194	0.000000	-.016212	0.000000	.001392	0.000000	.012917
3	.001194	0.000000	10.780336	0.000000	.001919	0.000000	-.028421	0.000000	.000013	0.000000
4	0.000000	.001194	0.000000	10.780336	0.000000	.001919	0.000000	-.028421	0.000000	.000013
5	.076820	0.000000	.001919	0.000000	10.798109	0.000000	.000540	0.000000	-.063474	0.000000
6	0.000000	.076820	0.000000	.001919	0.000000	10.798109	0.000000	.000540	0.000000	-.063474
7	.001392	0.000000	.124575	0.000000	.000540	0.000000	10.779576	0.000000	.001712	0.000000
8	0.000000	.001392	0.000000	.124575	0.000000	.000540	0.000000	10.779576	0.000000	.001712
9	.041343	0.000000	.000013	0.000000	.122561	0.000000	.001712	0.000000	10.792489	0.000000
10	0.000000	.041343	0.000000	.000013	0.000000	.122561	0.000000	.001712	0.000000	10.792489

DECOUPLED COEFFICIENT OF THE DERIVATIVE OF B(P): C(2,J,P)

J \ P	11	12	13	14	15	16	17	18	19	20
1	-10.780970	0.000000	-.000268	0.000000	-.008961	0.000000	-.000371	0.000000	-.008303	0.000000
2	0.000000	-10.780970	0.000000	-.000268	0.000000	-.008961	0.000000	-.000371	0.000000	-.008303
3	-.000268	0.000000	-10.765183	0.000000	-.000561	0.000000	-.022107	0.000000	.000128	0.000000
4	0.000000	-.000268	0.000000	-10.765183	0.000000	-.000561	0.000000	-.022107	0.000000	.000128
5	-.011921	0.000000	-.000561	0.000000	-10.779284	0.000000	-.000063	0.000000	-.007968	0.000000
6	0.000000	-.011921	0.000000	-.000561	0.000000	-10.779284	0.000000	-.000063	0.000000	-.007968
7	-.000371	0.000000	-.026976	0.000000	-.000063	0.000000	-10.765670	0.000000	-.000537	0.000000
8	0.000000	-.000371	0.000000	-.026976	0.000000	-.000063	0.000000	-10.765670	0.000000	-.000537
9	-.009207	0.000000	.000128	0.000000	-.013887	0.000000	-.000537	0.000000	-10.776299	0.000000
10	0.000000	-.009207	0.000000	.000128	0.000000	-.013887	0.000000	-.000537	0.000000	-10.776299

DECOUPLED COEFFICIENT OF THE COMBUSTION TERM C(3,J,P)

J \ P	1	2	3	4	5	6	7	8	9	10
1	-.027521	0.000000	-.000575	0.000000	-.026929	0.000000	-.000489	0.000000	-.025779	0.000000
2	0.000000	-.027521	0.000000	-.000575	0.000000	-.026929	0.000000	-.000489	0.000000	-.025779
3	-.000575	0.000000	-.027079	0.000000	-.000519	0.000000	-.026221	0.000000	-.000412	0.000000
4	0.000000	-.000575	0.000000	-.027079	0.000000	-.000519	0.000000	-.026221	0.000000	-.000412
5	-.026929	0.000000	-.000519	0.000000	-.026371	0.000000	-.000441	0.000000	-.025289	0.000000
6	0.000000	-.026929	0.000000	-.000519	0.000000	-.026371	0.000000	-.000441	0.000000	-.025289
7	-.000489	0.000000	-.026221	0.000000	-.000441	0.000000	-.025439	0.000000	-.000350	0.000000
8	0.000000	-.000489	0.000000	-.026221	0.000000	-.000441	0.000000	-.025439	0.000000	-.000350
9	-.025779	0.000000	-.000412	0.000000	-.025289	0.000000	-.000350	0.000000	-.024335	0.000000
10	0.000000	-.025779	0.000000	-.000412	0.000000	-.025289	0.000000	-.000350	0.000000	-.024335

DECOUPLED COEFFICIENT OF THE COMBUSTION TERM C(3,J,P)

J \ P	11	12	13	14	15	16	17	18	19	20
1	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
3	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
7	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
9	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

DECOUPLED COEFFICIENT OF THE COMBUSTION TERM C(3,J,P)

J \ P	1	2	3	4	5	6	7	8	9	10
1	0.000000	.027521	0.000000	.000575	0.000000	.026929	0.000000	.000489	0.000000	.025779
2	-.027521	0.000000	-.000575	0.000000	-.026929	0.000000	-.000489	0.000000	-.025779	0.000000
3	0.000000	.000575	0.000000	.027079	0.000000	.000519	0.000000	.026221	0.000000	.000412
4	-.000575	0.000000	-.027079	0.000000	-.000519	0.000000	-.026221	0.000000	-.000412	0.000000
5	0.000000	.026929	0.000000	.000519	0.000000	.026371	0.000000	.000441	0.000000	.025289
6	-.026929	0.000000	-.000519	0.000000	-.026371	0.000000	-.000441	0.000000	-.025289	0.000000
7	0.000000	.000489	0.000000	.026221	0.000000	.000441	0.000000	.025439	0.000000	.000350
8	-.000489	0.000000	-.026221	0.000000	-.000441	0.000000	-.025439	0.000000	-.000350	0.000000
9	0.000000	.025779	0.000000	.000412	0.000000	.025289	0.000000	.000350	0.000000	.024335
10	-.025779	0.000000	-.000412	0.000000	-.025289	0.000000	-.000350	0.000000	-.024335	0.000000

DECOUPLED COEFFICIENT OF THE COMBUSTION TERM C(3,J,P)

J \ P	11	12	13	14	15	16	17	18	19	20
1	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
3	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
7	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
9	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

COEFFICIENTS IN THE PARTICLE EQUATIONS: CPAR(J,P)

J \ P	1	2	3	4	5	6	7	8	9	10
1	-29.918623	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.000000	-29.918623	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
3	0.000000	0.000000	-29.918623	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
4	0.000000	0.000000	0.000000	-29.918623	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5	0.000000	0.000000	0.000000	0.000000	-29.918623	0.000000	0.000000	0.000000	0.000000	0.000000
6	0.000000	0.000000	0.000000	0.000000	0.000000	-29.918623	0.000000	0.000000	0.000000	0.000000
7	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	-29.918623	0.000000	0.000000	0.000000
8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	-29.918623	0.000000	0.000000
9	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	-29.918623	0.000000
10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	-29.918623

COEFFICIENTS IN THE PARTICLE EQUATIONS: CPAR(J,P)

J \ P	11	12	13	14	15	16	17	18	19	20
1	29.922420	0.000000	.000486	0.000000	-.020074	0.000000	.000415	0.000000	-.003663	0.000000
2	0.000000	29.922420	0.000000	.000486	0.000000	-.020074	0.000000	.000415	0.000000	-.003663
3	.000485	0.000000	29.933527	0.000000	.000442	0.000000	-.045928	0.000000	.000347	0.000000
4	0.000000	.000485	0.000000	29.933527	0.000000	.000442	0.000000	-.045928	0.000000	.000347
5	.026433	0.000000	.000439	0.000000	29.922671	0.000000	.000375	0.000000	-.045035	0.000000
6	0.000000	.026433	0.000000	.000439	0.000000	29.922671	0.000000	.000375	0.000000	-.045035
7	.000414	0.000000	.030574	0.000000	.000372	0.000000	29.931814	0.000000	.000301	0.000000
8	0.000000	.000414	0.000000	.030574	0.000000	.000372	0.000000	29.931814	0.000000	.000301
9	.010522	0.000000	.000349	0.000000	.047967	0.000000	.000295	0.000000	29.923115	0.000000
10	0.000000	.010522	0.000000	.000349	0.000000	.047967	0.000000	.000295	0.000000	29.923115

DECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION FOR B(1)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	0.000000	0.000000	18.666869	-.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
3	16.249851	-.000000	0.000000	0.000000	55.728268	0.000000	0.000000	0.000000	0.000000	0.000000
4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5	0.000000	0.000000	51.366570	-.000000	0.000000	0.000000	110.584197	-.000000	0.000000	0.000000
6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
7	0.000000	0.000000	0.000000	0.000000	104.477820	0.000000	0.000000	0.000000	183.434655	0.000000
8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
9	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	175.583599	-.000000	0.000000	0.000000
10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

DECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION FOR B(2)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.000000	0.000000	-.000000	18.866869	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
3	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
4	-.000000	16.249851	0.000000	0.000000	0.000000	55.728268	0.000000	0.000000	0.000000	0.000000
5	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6	0.000000	0.000000	-.000000	51.366570	0.000000	0.000000	-.000000	110.584197	0.000000	0.000000
7	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
8	0.000000	0.000000	0.000000	0.000000	0.000000	104.477820	0.000000	0.000000	0.000000	183.434655
9	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	-.000000	175.583599	0.000000	0.000000

DECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION FOR B(3)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	-10.741944	0.000000	0.000000	0.000000	28.736474	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
3	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	75.467477	-.000000	0.000000	0.000000
4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5	21.757757	-.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	140.193010	-.000000
6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
7	0.000000	0.000000	64.555402	-.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
9	0.000000	0.000000	0.000000	0.000000	126.235577	0.000000	0.000000	0.000000	0.000000	0.000000
10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

DECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION FOR B(4)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.000000	-10.741944	0.000000	0.000000	0.000000	28.736474	0.000000	0.000000	0.000000	0.000000
3	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	-.000000	75.467477	0.000000	0.000000
5	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6	-.000000	21.757757	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	-.000000	140.193010
7	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
8	0.000000	0.000000	-.000000	64.999402	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
9	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
10	0.000000	0.000000	0.000000	0.000000	0.000000	126.235577	0.000000	0.000000	0.000000	0.000000

DECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION FOR B(5)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	0.000000	0.000000	-20.611548	0.000000	0.000000	0.000000	38.606078	0.000000	0.000000	0.000000
2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
3	-23.228567	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	95.206686	0.000000
4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
7	25.520984	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
9	0.000000	0.000000	76.687555	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

DECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION FOR B(6)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.000000	0.000000	0.000000	-20.611548	0.000000	0.000000	0.000000	38.606078	0.000000	0.000000
3	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
4	0.000000	-23.228567	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	95.206686
5	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
7	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
8	0.000000	25.520984	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
9	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
10	0.000000	0.000000	0.000000	76.887555	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

DECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION FOR B(7)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	0.000000	0.000000	0.000000	0.000000	-30.481153	.000000	0.000000	0.000000	48.475682	-.000000
2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
3	0.000000	0.000000	-42.967776	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5	-37.459869	.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
7	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
9	27.539533	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

DECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION FOR B(8)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.000000	0.000000	0.000000	0.000000	.000000	-30.481153	0.000000	0.000000	-.000000	48.475662
3	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
4	0.000000	0.000000	0.000000	-42.967776	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6	.000000	-37.459869	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
7	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
9	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
10	0.000000	27.539533	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

DECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION FOR B(9)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	-40.350757	.000000	0.000000	0.000000
2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
3	0.000000	0.000000	0.000000	0.000000	-62.706985	.000000	0.000000	0.000000	0.000000	0.000000
4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5	0.000000	0.000000	-67.068683	.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
7	-53.435851	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
9	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

DECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION FOR B(10)

P \ Q	1	2	3	4	5	6	7	8	9	10
1	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	.000000	-40.350757	0.000000	0.000000
3	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
4	0.000000	0.000000	0.000000	0.000000	.000000	-62.706985	0.000000	0.000000	0.000000	0.000000
5	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6	0.000000	0.000000	.000000	-67.068683	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
7	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
8	0.000000	-53.435851	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
9	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
10	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

FORTRAN Source Code.

```
      PROGRAM TB1(INPUT,OUTPUT,DATA,
     1                TAPE5=INPUT,TAPE6=OUTPUT,TAPE9=DATA)
C
C
C          THIS PROGRAM COMPUTES THE COEFFICIENTS WHICH APPEAR
C     IN THE DIFFERENTIAL EQUATIONS WHICH GOVERN THE MODE-AMPLITUDE
C     FUNCTIONS.  THESE COEFFICIENTS CAN BE WRITTEN INTO A FILE
C     FOR INPUT TO PROGRAM TB2.
C
C     THE FOLLOWING INPUTS ARE REQUIRED:
C
C     THE FIRST CARD GIVES THE TITLE OF THE CASE.
C
C     SECOND CARD: GAM, BETA, BETAV, RRL, UB, VL, EL
C          GAM IS THE SPECIFIC HEAT RATIO.
C          BETA IS THE RATIO OF THE LENGTH OF THE TWO CUP GRAINS
C          TO THE LENGTH OF THE T-BURNER.
C          BETAV IS THE RATIO OF THE VENT WIDTH TO THE LENGTH
C             OF THE BURNER.
C          RRL IS THE RADIUS-TO-LENGTH RATIO.
C          UB IS THE VELOCITY AT THE BURNING SURFACE.
C          VL DETERMINES THE VENT EFFECT:
C             VL = 0     VENT GAIN.
C             VL = 1     NO EFFECT.
C             VL = 2     VENT LOSS.
C          EL IS THE EFFECTIVE VENT LENGTH.
C
C     THIRD CARD: NJMAX, NONLIN, NEGL, NOUT, NPRTKL, NBURN
C          NJMAX IS THE NUMBER OF MODE-AMPLITUDE FUNCTIONS IN THE ASSUMED
C          SERIES SOLUTION.
C          THE COEFFICIENTS COMPUTED ARE DETERMINED BY NONLIN AS FOLLOWS:
C             NONLIN = 0   LINEAR COEFFICIENTS ONLY
C             NONLIN = 1   BOTH LINEAR AND NONLINEAR COEFFICIENTS.
C          COEFFICIENTS TO BE NEGLECTED ARE DETERMINED BY NEGL
C          AS FOLLOWS:
C             NEGL = 0   TERMS SMALLER THAN 0.00001 ARE NEGLECTED.
C             NEGL = 1   LINEAR TERMS SMALLER THAN SM1 AND NONLINEAR
C                        TERMS SMALLER THAN SM2 ARE NEGLECTED.
C          THE OUTPUT IS DETERMINED BY NOUT AS FOLLOWS:
C             NOUT = 0   PRINTED OUTPUT ONLY
C             NOUT = 1   WRITE INTO A FILE AND PRINT OUTPUT.
C             NOUT = 2   WRITE INTO A FILE ONLY.
C          NPRTKL DETERMINES WHETHER THE PARTICLES ARE PRESENT:
C             NPRTKL = 0   PARTICLES NOT PRESENT.
C             NPRTKL = 1   PARTICLES PRESENT.
C          NBURN INDICATES WHETHER END BURNING IS PRESENT:
C             NBURN = 0   NOT PRESENT.
C             NBURN = 1   PRESENT.
C
```

```
C     NEXT CARD ( ONLY IF NPRTKL=1): DIA, RHOM, SP, TEMP, FREQ, CM
C          DIA IS THE PARTICLE DIAMETER, IN MICRONS.
C          RHOM IS THE DENSITY OF THE PARTICLE MATERIAL, IN KG/M**3.
C          SP IS THE RATIO OF THE SPECIFIC HEATS OF PARTICLE MATERIAL
C               AND GAS.
C          TEMP IS THE CHAMBER TEMPERATURE, IN DEGREES KELVIN.
C          FREQ IS THE FREQUENCY OF OSCILLATION IN PURE GAS, IN HERTZ.
C          CM IS THE PARTICLE LOADING.
C
C     NEXT CARD (NECESSARY ONLY IF NEGL = 1): SM1, SM2
C          SM1 AND SM2 ARE AS DEFINED ABOVE.
C
C     NEXT NJMAX CARDS: J, L(J), NAME(J)
C          EACH MODE-AMPLITUDE IS ASSIGNED AN INTEGER J.
C          THE MODE IS SPECIFIED BY THE INDEX L(J).
C          L(J) IS THE AXIAL MODE NUMBER AND MUST NOT EXCEED NJMAX.
C          NAME(J) IS A FOUR-CHARACTER NAME FOR THE J TH MODE.
C
C
C     ******************************************************************
C
C
C
      DIMENSION     L(6), NAME(6), TITLE(7), V(2), JC(12), C(4,12,24),
     1              C1(12,12), D(12,12,12), KMAX(5), TSQ(12), TS(4,12),
     2              C1PAR(12,12), CPAR(12,24), TSPAR(12), AXINT(2),
     3              AX(11), CC(4,6,12), CNORM(12), CCPAR(2,6,12),
     4              CCV(6), CV(12), TSV(12)
      COMPLEX       CD1(6,6,6), CD2(6,6,6), CD3(6,6,6), CD4(6,6,6), CI
      COMMON        B(6)
      COMMON        /BLK7/BETA, BETAV, RRL, UB, PARTKL, CM, NPRTKL, NBURN
C
C     DATA INPUT.
C
      MAXMD = 6
      MAXMD2 = 12
      MAXMD4 = 24
      PI = 3.1415926536
      SM1 = 0.00001
      SM2 = 0.00001
      CI = (0.0,1.0)
C
C     INPUT PARAMETERS.
    4 READ (5,5000)   TITLE
      IF (EOF(5)) 600, 1
    1 CONTINUE
      READ (5,5001) GAM, BETA, BETAV, RRL, UB, VL, EL
      READ (5,5004) NJMAX, NONLIN, NEGL, NOUT, NPRTKL, NBURN
      IF (NPRTKL .EQ. 1) READ (5,5006) DIA, RHOM, SP, TEMP, FREQ, CM
      GAMMA = GAM * (1.0 + SP*CM) / (1.0 + GAM*SP*CM)
      IF (NEGL .EQ. 1) READ (5,5005) SM1, SM2
      DO 10 I = 1, NJMAX
      READ (5,5002) J, L(J), NAME(J)
      B(I) = PI * I
   10 CONTINUE
```

```
C
      NJMAX2 = NJMAX
      IF (NPRTKL .EQ. 1) NJMAX2 = 2 * NJMAX
      ZE = 1.0
      ZCOMB = 1.0
      CAX = GAMMA + 1.0
      AV = PI * BETAV * BETAV / 4.0
      BETAV1 = PI * (BETAV + 1.0) / 2.0
      BETAV2 = PI * (BETAV - 1.0) / 2.0
      IF (NPRTKL .EQ. 0) GO TO 14
      VISC = 8.834 * 0.00001 * (TEMP/3485.)**0.66
      PARTKL = (9.0 * VISC) / (RHOM * FREQ * DIA * DIA *10.**(-12))
   14 CONTINUE
C
C     CALCULATE LINEAR COEFFICIENTS.
C
      DO 100 NJ = 1, NJMAX
C
      IF (BETAV .LT. 0.00001) GO TO 110
      CCV(NJ) = AV * (SIN(NJ*BETAV1) - SIN(NJ*BETAV2))
     1          / (BETAV * NJ * PI)
  110 DO 100 NP = 1, NJMAX2
C
C     ZERO COEFFICIENT ARRAYS.
      DO 105 KC = 1, 4
      CC(KC,NJ,NP) = (0.0,0.0)
  105 CONTINUE
      CCPAR(1,NJ,NP) = CCPAR(2,NJ,NP) = 0.0
      NPM = NP
      NJM = NJ
      IF (NP .GT. NJMAX) NPM = NP - NJMAX
C
C     CALCULATE AXIAL INTEGRALS.
      DO 130 NOPT = 1, 11
      CALL AXIAL1(NOPT,NPM,NJM,CRSLT)
      AX(NOPT) = CRSLT
  130 CONTINUE
C
C     EVALUATE FUNCTIONS AT THE END.
      ZEJ = COS(B(NJM) * ZE)
      ZEP1 = COS(B(NPM) * ZE)
C
      IF (NP .GT. NJMAX) GO TO 704
C
C     COEFFICIENT OF THE SECOND DERIVATIVE OF A(P).
      CC(1,NJ,NP) = AX(1)
C
C     COEFFICIENT OF A(P).
      CC(2,NJ,NP) = - AX(2)
C
```

```
C       COEFFICIENT OF THE FIRST DERIVATIVE OF A(P).
      CC(3,NJ,NP) = 2.0*AX(4) + CAX*AX(3) + PARTKL*AX(5) -
     1              VL*AX(11) + GAMMA * UB * NBURN * (1.0 + ZEJ*ZEP1)
      CC(4,NJ,NP) = - GAMMA * (AX(9) + UB * NBURN * (1.0+ZEJ*ZEP1))
      CCPAR(2,NJ,NP) = - PARTKL * AX(1)
      GO TO 100
C
  704 CC(3,NJ,NP) = - PARTKL * AX(5) - (GAMMA - 1.0) * AX(6)
      CCPAR(1,NJ,NP) = AX(1)
      CCPAR(2,NJ,NP) = PARTKL*AX(1) + AX(7) + AX(8) - VL*AX(10)
C
  100 CONTINUE
C
C     NORMALIZE LINEAR COEFFICIENTS.
      DO 140 NJ = 1, NJMAX
      CNORM(NJ) = CC(1,NJ,NJ)
      CV(NJ) = CV(NJ) / CNORM(NJ)
      DO 140 NP = 1, NJMAX2
      DO 140 KC = 1, 4
      CC(KC,NJ,NP) = CC(KC,NJ,NP)/CNORM(NJ)
  140 CONTINUE
C
      IF (NPRTKL .EQ. 0) GO TO 1005
      DO 1030 NJ = 1,NJMAX
      NJM = NJ + NJMAX
      CNORM(NJM) = CCPAR(1,NJ,NJM)
      DO 1030 NP = 1, NJMAX2
      DO 1030 KC = 1, 2
      CCPAR(KC,NJ,NP) = CCPAR(KC,NJ,NP)/CNORM(NJM)
 1030 CONTINUE
 1005 CONTINUE
C
C     ****************************************************************
C
C     COMPUTE NONLINEAR COEFFICIENTS.
C
      IF (NONLIN .EQ. 0)  GO TO 402
      G1 = (GAMMA - 1.0) * 0.5
C
      DO 200 NJ = 1, NJMAX
      DCOEF = 0.5 / CNORM(NJ)
      DO 200 NP = 1, NJMAX
      DO 200 NQ = 1, NJMAX
C
      CD1(NJ,NP,NQ) = (0.0,0.0)
      CD2(NJ,NP,NQ) = (0.0,0.0)
      CD3(NJ,NP,NQ) = (0.0,0.0)
      CD4(NJ,NP,NQ) = (0.0,0.0)
C
      DO 240 J = 1, 2
      CALL AXIAL2(J,NP,NQ,NJ,CRSLT)
      AXINT(J) = CRSLT
  240 CONTINUE
```

```
C
      CD1(NJ,NP,NQ) = CD4(NJ,NP,NQ) = (AXINT(1) + G1 * AXINT(2)) *
     1               DCOEF * (1.0,-1.0)
      CD2(NJ,NP,NQ) = CD3(NJ,NP,NQ) = (AXINT(1) + G1 * AXINT(2)) *
     1               DCOEF * (1.0,1.0)
  200 CONTINUE
C
C     ******************************************************************
C
C     CALCULATE COEFFICIENTS FOR EQUIVALENT REAL SYSTEM.
C
  402 DO 350 NJ = 1, NJMAX
      NEWJ = (2 * NJ) - 1
      NEWJ1 = NEWJ + 1
      CV(NEWJ) = CV(NEWJ1) = CCV(NJ)
      DO 360 NP = 1,NJMAX2
      NEWP = 2 * NP - 1
      NEWP1 = NEWP + 1
C
C     COEFFICIENTS OF LINEAR TERMS.
      IF (NP .GT. NJMAX) GO TO 1040
      C1(NEWJ,NEWP) = C1(NEWJ1,NEWP1) = CC(1,NJ,NP)
 1040 CONTINUE
      C(4,NEWJ,NEWP1) = - CC(4,NJ,NP)
      C(4,NEWJ1,NEWP) = CC(4,NJ,NP)
      DO 360 KC = 1, 3
      C(KC,NEWJ,NEWP) = C(KC,NEWJ1,NEWP1) = CC(KC+1,NJ,NP)
  360 CONTINUE
C
C
C     COEFFICIENTS OF NONLINEAR TERMS.
      IF (NONLIN .EQ. 0) GO TO 350
      DO 370 NP = 1, NJMAX
      NEWP = 2 * NP - 1
      NEWP1 = NEWP + 1
      DO 370 NQ = 1, NJMAX
      NEWQ = (2 * NQ) - 1
      NEWQ1 = NEWQ + 1
      CD1R = REAL(CD1(NJ,NP,NQ))
      CD1I = AIMAG(CD1(NJ,NP,NQ))
      CD2R = REAL(CD2(NJ,NP,NQ))
      CD2I = AIMAG(CD2(NJ,NP,NQ))
      CD3R = REAL(CD3(NJ,NP,NQ))
      CD3I = AIMAG(CD3(NJ,NP,NQ))
      CD4R = REAL(CD4(NJ,NP,NQ))
      CD4I = AIMAG(CD4(NJ,NP,NQ))
      D(NEWJ,NEWP,NEWQ) = CD1R + CD2R + CD3R + CD4R
      D(NEWJ,NEWP,NEWQ1) = -CD1I + CD2I - CD3I + CD4I
      D(NEWJ,NEWP1,NEWQ) = -CD1I - CD2I + CD3I + CD4I
      D(NEWJ,NEWP1,NEWQ1) = -CD1R + CD2R + CD3R - CD4R
```

```
      D(NEWJ1,NEWP,NEWQ) = CD1I + CD2I + CD3I + CD4I
      D(NEWJ1,NEWP,NEWQ1) = CD1R - CD2R + CD3R - CD4R
      D(NEWJ1,NEWP1,NEWQ) = CD1R + CD2R - CD3R - CD4R
      D(NEWJ1,NEWP1,NEWQ1) = -CD1I + CD2I + CD3I - CD4I
  370 CONTINUE
  350 CONTINUE
C
      IF (NPRTKL .EQ. 0) GO TO 1035
      DO 1050 NJ = 1, NJMAX
      NEWJ = 2 * NJ - 1
      NEWJ1 = NEWJ + 1
      DO 1050 NP = 1, NJMAX2
      NEWP = 2 * NP - 1
      NEWP1 = NEWP + 1
      CPAR(NEWJ,NEWP) = CPAR(NEWJ1,NEWP1) = CCPAR(2,NJ,NP)
      IF (NP .LE. NJMAX) GO TO 1050
      NEWP = NEWP - NJMAX2
      NEWP1 = NEWP + 1
      C1PAR(NEWJ,NEWP) = C1PAR(NEWJ1,NEWP1) = CCPAR(1,NJ,NP)
 1050 CONTINUE
 1035 CONTINUE
C
C     ****************************************************************
C
C     COMPUTE COEFFICIENTS FOR THE EQUATIONS WHICH ARE DECOUPLED
C     IN THE SECOND DERIVATIVES.
C
      DO 405 KC = 1, 5
      KMAX(KC) = 0
  405 CONTINUE
C
C     CALCULATE INVERSE OF THE MATRIX C1(I,J).
      JMAX = NJMAX
      NJMAX = 2 * NJMAX
      JMAX2 = NJMAX2
      NJMAX2 = 2 * NJMAX2
C
C
      V(1) = 1
      CALL GJR(C1,MAXMD2,MAXMD2,NJMAX,0,JC,V)
C
C     USE INVERSE TO CALCULATE DECOUPLED COEFFICIENTS.
C
C
C     LINEAR COEFFICIENTS.
      DO 430 NP = 1, NJMAX2
      DO 420 NJ = 1, NJMAX
      DO 420 KC = 1, 4
      TS(KC,NJ) = 0.0
      DO 420 K = 1, NJMAX
      TS(KC,NJ) = TS(KC,NJ) + C1(NJ,K) * C(KC,K,NP)
  420 CONTINUE
```

```
      DO 430 NJ = 1, NJMAX
      DO 430 KC = 1, 4
      C(KC,NJ,NP) = TS(KC,NJ)
      ABSVAL = ABS(C(KC,NJ,NP))
      IF (ABSVAL .GE. SM1)  KMAX(KC) = KMAX(KC) + 1
  430 CONTINUE
C
      DO 720 NJ = 1, NJMAX
      TSV(NJ) = 0.0
      DO 720 K = 1, NJMAX
      TSV(NJ) = TSV(NJ) + C1(NJ,K) * CV(K)
  720 CONTINUE
      DO 730 NJ = 1, NJMAX
      CV(NJ) = TSV(NJ)
  730 CONTINUE
C
      IF (NPRTKL .EQ. 0) GO TO 1060
      KMAXPR = 0
      V(1) = 1
      CALL GJR(C1PAR,MAXMD2,MAXMD2,NJMAX,0,JC,V)
      DO 1065 NP = 1, NJMAX2
      DO 1070 NJ = 1, NJMAX
      TSPAR(NJ) = 0.0
      DO 1070 K = 1, NJMAX
      TSPAR(NJ) = TSPAR(NJ) + C1PAR(NJ,K)*CPAR(K,NP)
 1070 CONTINUE
      DO 1065 NJ = 1,NJMAX
      CPAR(NJ,NP)=TSPAR(NJ)
      ABSVAL = ABS(CPAR(NJ,NP))
      IF (ABSVAL .GE. SM1) KMAXPR = KMAXPR + 1
 1065 CONTINUE
 1060 CONTINUE
C
C     NONLINEAR COEFFICIENTS.
      IF (NONLIN .EQ. 0) GO TO 410
      DO 735 NP = 1, NJMAX
      DO 735 NQ = 1, NJMAX
      DO 440 NJ = 1, NJMAX
      TSQ(NJ) = 0.0
      DO 440 K = 1, NJMAX
      TSQ(NJ) = TSQ(NJ) + C1(NJ,K) * D(K,NP,NQ)
  440 CONTINUE
      DO 445 NJ = 1, NJMAX
      D(NJ,NP,NQ) = TSQ(NJ)
      ABSVAL = ABS(D(NJ,NP,NQ))
      IF (ABSVAL .GT. SM2) KMAX(5) = KMAX(5) + 1
  445 CONTINUE
  735 CONTINUE
  410 CONTINUE
C
```

```
C     ******************************************************************
C     OUTPUT.
C
      IF (NOUT .EQ. 2) GO TO 455
      WRITE (6,6001) TITLE
      WRITE (6,6002)  GAM, BETA, BETAV, RRL, UB, VL
      IF (NBURN .EQ. 0) WRITE (6,6025)
      IF (NBURN .EQ. 1) WRITE (6,6026)
      IF (NPRTKL .EQ. 0) WRITE (6,6022)
      IF (NPRTKL .EQ. 1) WRITE (6,6021) DIA, CM, FREQ,
     1                          TEMP, SP, RHOM, PARTKL
      WRITE (6,6004)
      DO 310 J = 1, JMAX
      WRITE (6,6003) NAME(J), J, L(J), B(J)
  310 CONTINUE
      IF (NONLIN .EQ. 0)  WRITE (6,6013)
C
C     OUTPUT OF LINEAR COEFFICIENTS.
      DO 320 KC = 1, 4
      NJS = 0
      NJF = 0
      KOUNTJ = 1
  758 NJS = NJF + 1
      NJF = 10 * KOUNTJ
      IF (NJF .GT. NJMAX) NJF = NJMAX
      NPS = 0
      NPF = 0
      KOUNTP = 1
  754 NPS = NPF + 1
      NPF = 10 * KOUNTP
      IF (NPF .GT. NJMAX2) NPF = NJMAX2
      IF (KC .EQ. 1)  WRITE (6,6005)
      IF (KC .EQ. 2)  WRITE (6,6006)
      IF (KC .EQ. 3 .OR. KC .EQ. 4)  WRITE (6,6007)
      WRITE (6,6008) (NP, NP = NPS, NPF)
      WRITE (6,6014)
      DO 750 NJ = NJS, NJF
      WRITE (6,6009) NJ, (C(KC,NJ,NP), NP = NPS, NPF)
  750 CONTINUE
      IF (NPF .EQ. NJMAX2) GO TO 752
      KOUNTP = KOUNTP + 1
      GO TO 754
  752 IF (NJF .EQ. NJMAX) GO TO 756
      KOUNTJ = KOUNTJ + 1
      GO TO 758
  756 CONTINUE
  320 CONTINUE
C
      IF (NPRTKL .EQ. 0) GO TO 1080
      NJS = 0
      NJF = 0
      KOUNTJ = 1
```

```
C
 1072 NJS = NJF + 1
      NJF = 10*KOUNTJ
      IF (NJF .GT. NJMAX) NJF = NJMAX
      NPS = 0
      NPF = 0
      KOUNTP = 1
 1074 NPS = NPF+1
      NPF = 10*KOUNTP
      IF (NPF .GT.NJMAX2) NPF = NJMAX2
      WRITE (6,6023)
      WRITE (6,6008) (NP, NP = NPS,NPF)
      WRITE (6,6014)
      DO 1076 NJ = NJS,NJF
      WRITE (6,6009) NJ, (CPAR(NJ,NP),NP = NPS,NPF)
 1076 CONTINUE
      IF (NPF .EQ. NJMAX2) GO TO 1078
      KOUNTP = KOUNTP + 1
      GO TO 1074
 1078 IF (NJF .EQ. NJMAX) GO TO 1080
      KOUNTJ = KOUNTJ + 1
      GO TO 1072
 1080 CONTINUE
C     OUTPUT OF NONLINEAR COEFFICIENTS.
      IF (NONLIN .EQ. 0)  GO TO 452
      DO 400 NJ = 1, NJMAX
      NPS = 0
      NPF = 0
      KOUNTP = 1
  780 NPS = NPF + 1
      NPF = 10 * KOUNTP
      IF (NPF .GT. NJMAX) NPF = NJMAX
      NQS = 0
      NQF = 0
      KOUNTQ = 1
  776 NQS = NQF + 1
      NQF = 10 * KOUNTQ
      IF (NQF .GT. NJMAX) NQF = NJMAX
      IF (NQS .GT. NJMAX .AND. NPF .LE. NJMAX) GO TO 771
      IF (NQF .LE. NJMAX .AND. NPS .GT. NJMAX) GO TO 771
      WRITE (6,6010) NJ
      WRITE (6,6011) (NQ, NQ = NQS, NQF)
      WRITE (6,6015)
      DO 772 NP = NPS, NPF
      WRITE (6,6009) NP, (D(NJ,NP,NQ), NQ = NQS, NQF)
  772 CONTINUE
  771 CONTINUE
      IF (NQF .EQ. NJMAX) GO TO 774
      KOUNTQ = KOUNTQ + 1
      GO TO 776
```

```
774 IF (NPF .EQ. NJMAX) GO TO 778
    KOUNTP = KOUNTP + 1
    GO TO 780
778 CONTINUE
400 CONTINUE
452 CONTINUE
    IF (NOUT .EQ. 0) GO TO 4
C
C     WRITE COEFFICIENTS ON FILE.
C
455 WRITE (9,7001) GAMMA, BETA, BETAV, RRL, UB, VL, EL,
   1              NJMAX, NPRTKL, NBURN
    IF (NPRTKL .EQ. 1) WRITE (9,7007) DIA, RHOM, SP,
   1                                  TEMP, FREQ, PARTKL, CM
C
    DO 450 J = 1, JMAX
    WRITE (9,7002)  J, L(J), NAME(J)
450 CONTINUE
C
    DO 457 J = 1, JMAX
    WRITE (9,7006) J, B(J)
457 CONTINUE
C
    DO 460 KC = 1, 4
    WRITE (9,7003) KMAX(KC)
    DO 460 NJ = 1, NJMAX
    DO 460 NP = 1, NJMAX2
    ABSVAL = ABS(C(KC,NJ,NP))
    IF (ABSVAL .GE. SM1)  WRITE (9,7004)  NJ, NP, C(KC,NJ,NP)
460 CONTINUE
C
    DO 465 NJ = 1, NJMAX
    WRITE (9,7008) NJ, CV(NJ)
465 CONTINUE
C
    WRITE (9,7003) KMAXPR
    DO 1082 NJ = 1, NJMAX
    DO 1082 NP = 1, NJMAX2
    ABSVAL = ABS(CPAR(NJ,NP))
    IF (ABSVAL .GE. SM1) WRITE (9,7004)NJ,NP,CPAR(NJ,NP)
1082 CONTINUE
C
    WRITE (9,7003) KMAX(5)
    IF (NONLIN .EQ. 0)  GO TO 4
    DO 470 NJ = 1, NJMAX
    DO 470 NP = 1, NJMAX
    DO 470 NQ = 1, NJMAX
    ABSVAL = ABS(D(NJ,NP,NQ))
    IF (ABSVAL .GE. SM2)  WRITE (9,7005) NJ, NP, NQ, D(NJ,NP,NQ)
470 CONTINUE
    GO TO 4
```

```
C
  600 CONTINUE
C
C     ******************************************************************
C
C     FORMAT SPECIFICATIONS.
 5000 FORMAT (7A10)
 5001 FORMAT (7F10.0)
 5002 FORMAT (2I5, 1X, A4)
 5004 FORMAT (6I5)
 5005 FORMAT (2F10.0)
 5006 FORMAT (6F10.0)
 6001 FORMAT (1H1,//,2X,7A10//)
 6002 FORMAT (2X,8HGAMMA = ,F5.3,//,2X,6HBETA =,F5.3,//,2X,7HBETAV =,
     1       F7.5,//,2X,5HR/L =,F7.5,//,2X,4HUB =,F7.5,//,2X,
     2       5HVL = ,F4.2,/)
 6003 FORMAT (2X,A4,2I5,2F10.5/)
 6004 FORMAT (2X////2X,14HNAME     J     L,5X,4HB(J)//)
 6005 FORMAT (1H1,45H   DECOUPLED COEFFICIENT OF B(P):     C(1,J,P)///)
 6006 FORMAT (1H1,44H   DECOUPLED COEFFICIENT OF THE DERIVATIVE OF,
     1       6H B(P):,5X,8HC(2,J,P)///)
 6007 FORMAT (1H1,47H   DECOUPLED COEFFICIENT OF THE COMBUSTION TERM
     1       5X,8HC(3,J,P)///)
 6008 FORMAT (7X,1HP,I8,9I12)
 6009 FORMAT (2X//2X,I3,3X,10F12.6)
 6010 FORMAT (1H1,47HDECOUPLED NONLINEAR COEFFICIENT IN GAS EQUATION,
     1       7H FOR B(,I2,1H)///)
 6011 FORMAT (7X,1HQ,I8,9I12)
 6013 FORMAT (2X//2X,25HLINEAR COEFFICIENTS ONLY.)
 6014 FORMAT (4X,1HJ)
 6015 FORMAT (4X,1HP)
 6021 FORMAT (///,10X,27HPARTICLE DIA (IN MICRONS) = ,F5.2,10X,
     1       4HCM =,F4.2,10X,18HFREQ (IN HERTZ) = ,F6.1,//,
     2       10X,26HCHAMBER TEMP (IN DEG K) = ,F6.1,10X,4HSP =,
     3       F4.2,10X,27HRHOM (IN KG/CUBIC METER) = ,F6.1,//,10X,
     4       30HPARTICLE DRAG COEFFICIENT, K =,F8.4,////)
 6022 FORMAT (2X,26HPARTICLES ARE NOT PRESENT.//)
 6023 FORMAT (1H1,39HCOEFFICIENTS IN THE PARTICLE EQUATIONS:,
     1       12H   CPAR(J,P)///)
 6025 FORMAT (2X,15HNO END BURNING.,//)
 6026 FORMAT (2X,23HEND BURNING IS PRESENT.,//)
 7001 FORMAT (7F10.5,3I5)
 7002 FORMAT (2I5,1X,A4)
 7003 FORMAT (I5)
 7004 FORMAT (2I5,F15.8)
 7005 FORMAT (3I5,F15.8)
 7006 FORMAT (I5,2F12.8)
 7007 FORMAT (7F15.8)
 7008 FORMAT (I5,F12.8)
      END
```

```
      SUBROUTINE AXIAL1(NOPT,NP,NJ,RESULT)
C
C
C     THIS SUBROUTINE CALCULATES THE INTEGRAL OVER THE INTERVAL
C     (0,1) OF THE FOLLOWING FUNCTIONS ACCORDING TO THE VALUE
C     OF NOPT
C
C     NOPT = 1       Z(NP) * Z(NJ)
C     NOPT = 2       DDZ(NP) * Z(NJ)
C     NOPT = 3       DUBAR * Z(NP) * Z(NJ)
C     NOPT = 4       UBAR * DZ(NP) * Z(NJ)
C     NOPT = 5       RHOP * Z(NP) * Z(NJ)
C     NOPT = 6       RHOP * UPBAR * DZ(NP) * Z(NJ)
C     NOPT = 7       UPBAR * DZ(NP) * Z(NJ)
C     NOPT = 8       DUPBAR * Z(NP) * Z(NJ)
C
C     IN THE ABOVE EQUATIONS:
C     Z(NP) IS THE AXIAL ACOUSTIC EIGENFUNCTION OF INDEX NP.
C     Z(NJ) IS THE AXIAL ACOUSTIC EIGENFUNCTION OF INDEX NJ.
C     DZ AND DDZ ARE THE FIRST AND SECOND DERIVATIVES OF THE
C     AXIAL EIGENFUNCTIONS RESPECTIVELY.
C     UBAR IS THE STEADY STATE VELOCITY DISTRIBUTION AND
C     DUBAR IS ITS AXIAL DERIVATIVE.
C
C
      DIMENSION  FUNCT(250)
      COMMON     B(6)
      COMMON     /BLK7/  BETA, BETAV, RRL, UB, PARTKL, CM, NPRTKL, NBURN
C
      MAXMD = 6
      RESULT = 0.0
      ZE = 1.0
      BP = B(NP)
      BJ = B(NJ)
C
      IF (NOPT .GT. 2)  GO TO 50
C     CALCULATE INTEGRALS BY MEANS OF ANALYTICAL EXPRESSIONS FOR
C     NOPT = 1 AND NOPT = 2.
      IF (NP .EQ. NJ) RESULT = 0.5
      IF (NOPT .EQ. 2) RESULT = - BP * BP * RESULT
      RETURN
C
C     NUMERICAL EVALUATION OF INTEGRALS FOR NOPT > 2.
C
C     COMPUTE STEP SIZE FOR SIMPSON INTEGRATION.
   50 N = 200
      RN = N
      RESULT = 0.0
      NOPT2 = NOPT - 2
      IC = 1
      J = 1
      H = ZE/RN
      ZO = 0.0
      NP1 = N + 1
```

```
C
C       COMPUTE INTEGRANDS.
        DO 60 I = 1, NP1
        Z = Z0 + (I - 1) * H
        ARG = BP * Z
        CALL STEADY(Z, UBAR, UPBAR, RHOP, DUBAR, DUPBAR)
        GO TO (110, 120, 130, 140, 150, 155, 160, 170, 180), NOPT2
  110   F2 = COS(ARG)
        F1 = DUBAR
        GO TO 190
  120   F1 = UBAR
        F2 = - BP * SIN(ARG)
        GO TO 190
  130   F1 = RHOP
        F2 = COS(ARG)
        GO TO 190
  140   F1 = RHOP * UPBAR
        F2 = - BP * SIN(ARG)
        GO TO 190
  150   F1 = UPBAR
        F2 = - BP * SIN(ARG)
        GO TO 190
  155   F1 = DUPBAR
        F2 = COS(ARG)
        GO TO 190
  160   F1 = 0.0
        BETA2 = BETA/2.0
        IF (Z .GT. BETA2 .AND. Z .LT. 1.0-BETA2) GO TO 190
        F1 = DUBAR
        F2 = COS(ARG)
        GO TO 190
  170   BETAV2 = BETAV/2.0
        F1 = 0.0
        IF (Z .LT. 0.5-BETAV2 .OR. Z .GT. 0.5+BETAV2) GO TO 190
        F1 = DUPBAR
        F2 = COS(ARG)
        GO TO 190
  180   BETAV2 = BETAV/2.0
        F1 = 0.0
        IF (Z .LT. 0.5-BETAV2 .OR. Z .GT. 0.5+BETAV2) GO TO 190
        F1 = DUBAR
        F2 = COS(ARG)
  190   CONTINUE
        F3 = COS(BJ*Z)
        FUNCT(I) = F1 * F2 * F3
   60   CONTINUE
C
```

```
C     PERFORM SIMPSON INTEGRATION.
      NM1 = N - 1
      S1 = FUNCT(1) + FUNCT(NP1)
      S2 = 0.0
      S3 = 0.0
      DO 70 I = 2, N, 2
      S2 = S2 + FUNCT(I)
   70 CONTINUE
      DO 80 I = 3, NM1, 2
      S3 = S3 + FUNCT(I)
   80 CONTINUE
      RESULT = RESULT +
     1         H * (S1 + 4.0*S2 + 2.0*S3) / 3.0
   90 CONTINUE
C
  100 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE AXIAL2(NOPT,NP,NQ,NJ,RESULT)
C
C
C     THIS SUBROUTINE CALCULATES THE INTEGRAL OVER THE INTERVAL
C     (0,1) OF THE FOLLOWING FUNCTIONS ACCORDING TO THE VALUE OF NOPT.
C
C     NOPT = 1       DZ(NP) * DZ(NQ) * Z(NJ)
C     NOPT = 2       DDZ(NP) * Z(NQ) * Z(NJ)
C
C     IN THE ABOVE EQUATIONS:
C     Z(NP), Z(NQ), AND Z(NJ) ARE THE AXIAL ACOUSTIC EIGENFUNCTIONS
C     AND NP, NQ, AND NJ ARE THEIR INDICES.
C     DZ IS THE FIRST DERIVATIVE OF THE AXIAL EIGENFUNCTIONS.
C     DDZ IS THE SECOND DERIVATIVE OF THE AXIAL EIGENFUNCTIONS.
C
      COMMON   B(6)
C
C     CALCULATE INTEGRALS BY MEANS OF ANALYTICAL EXPRESSIONS.
      BP = B(NP)
      BQ = B(NQ)
      BJ = B(NJ)
      RESULT = 0.0
      IF (NOPT .EQ. 2) GO TO 10
      IF (NP-NQ+NJ .EQ. 0 .OR. NP-NQ-NJ .EQ. 0) RESULT = BP * BQ / 4.0
      IF (NP+NQ-NJ .EQ. 0) RESULT = - BP * BQ / 4.0
      RETURN
   10 CONTINUE
      IF (NP+NQ-NJ .EQ. 0 .OR.
     1    NP-NQ+NJ .EQ. 0 .OR.
     2    NP-NQ-NJ .EQ. 0) RESULT = - (BP * BP) / 4.0
      RETURN
      END
```

```
      SUBROUTINE STEADY(X,UBAR,UPBAR,RHOP,DUBAR,DUPBAR)
C
      COMMON   /BLK7/ BETA, BETAV, RRL, UB, PARTKL, CM, NPRTKL, NBURN
C
      RLR = 1.0/RRL
      BBY2 = BETA/2.0
      BVBY2 = BETAV/2.0
      IF (NPRTKL .EQ. 1) A5 = (4.0*UB) / (RRL*PARTKL)
      IF (X .GE. BBY2) GO TO 10
      UBAR = UB * (NBURN + 2.0 * RLR * X)
      UPBAR = UBAR / (1.0 + A5)
      RHOP = CM * (1.0 + A5)
      DUBAR = 2.0 * UB * RLR
      DUPBAR = DUBAR / (1.0+A5)
      RETURN
   10 A4 = NBURN + BETA*RLR
      IF (X .GE. 0.5-BVBY2) GO TO 20
      UBAR = UB * A4
      UPBAR = UBAR
      RHOP = CM
      DUBAR = DUPBAR = 0.0
      RETURN
   20 IF (X .GT. 0.5+BVBY2) GO TO 30
      X1 = (1.0 - 2.0*X) / BETAV
      UBAR = UB * A4 * X1
      A6 = 1.0
      IF (NPRTKL .EQ. 1) A6 = 1.0 - (4.0*UB*A4) / (PARTKL*BETAV)
      UPBAR = UBAR / A6
      RHOP = CM * A6
      DUBAR = - (2.0 * UB * A4) / BETAV
      DUPBAR = DUBAR / A6
      RETURN
   30 IF (X .GT. 1.0-BBY2) GO TO 40
      UBAR = -  UB * A4
      UPBAR = UBAR
      RHOP = CM
      DUBAR = DUPBAR = 0.0
      RETURN
   40 X1 = NBURN + 2.0 * (1.0 - X) * RLR
      UBAR = - UB * X1
      UPBAR = UBAR / (1.0 + A5)
      RHOP = CM * (1.0 + A5)
      DUBAR = 2.0 * RLR * UB
      DUPBAR = DUBAR / (1.0+A5)
      RETURN
      END
```

4.2 PROGRAM TB2.

Program TB2 calculates the nonlinear stability characteristics of a T-burner according to the approximate analysis (Galerkin method) described in Volume I. Using the coefficients generated by TB1, this program integrates the system of differential equations governing the mode amplitudes and computes the time history of a pressure disturbance in the T-burner.

Program Structure. This program performs the same calculations for the T-burner that SOLID2 performs for the motor, and its structure is similar to the structure of SOLID2. In fact, the description of the structure of SOLID2 given in Section 3.2 adequately describes the structure of TB2 if "SOLID1" and "SOLID2" are replaced by "TB1" and "TB2" respectively.

Description of Input. As in the case of Program SOLID2, the input data required to run this program consists of three parts: (1) the control numbers NØUTCF and NHISTR which determine the extent of desired printed output, (2) the parameters and coefficients generated by Program TB1, and (3) data describing the case to be run. The information to be provided for each case is the same as for Program SØLID2. The general description of format given in Sections 3.1 and 3.2 apply here also. A list of necessary inputs is described below.

The three parts of the input are:

(1) The control numbers, NØUTCF and NHISTR.

(2) The coefficients from Program TB1.

(3) The data deck.

The first card gives the control numbers, NØUTCF and NHISTR.

NØUTCF determines printout of coefficients:

If NØUTCF = 0 coefficients are not printed out.

If NØUTCF = 1 only linear coefficients are printed out.

If NOUTCF = 2 all coefficients are printed out.

NHISTR determines if pressure history is to be printed:

If NHISTR = 0 printed

If NHISTR = 1 not printed.

The coefficients are obtained from Program TB1 by putting NØUT = 1 or NØUT = 2, thereby writing the coefficients into a disk. This disk has been given the device number 9.

The data deck consists of the following cards:

First card: Title of the case.

Second card: H, TSTART, TQUIT, FREQ, BCØMB

H is the integration step size.

TSTART is the time at which output starts.

TQUIT is the time at which computations are terminated.

FREQ is the motor frequency (in pure gas), in Hertz.

BCØMB is the combustion response nonlinearity factor.

Third card: A2PARA, B2PARA, EN, ØMEGA

A2PARA and B2PARA are the combustion parameters in the A-B model.

EN is the pressure exponent in the burning rate law.

ØMEGA is the frequency nondimensionalized by the square of the steady-state burning rate.

Fourth card: NLØC, NTERMS, NØUT, NCØMB

NLØC determines the location of the wall pressure maxima and minima:

If NLØC = 1 location is x = 0.0

If NLØC = 2 location is x = 1.0

If NLØC = 3 location is x = 0.5

NTERMS is the number of terms given initial values.

NØUT is the output control number.

If NØUT = 0 printed output only.

If NØUT > 0 both printed and plotted output:

If NØUT = 1 plot of pressure at x = 0.0 only.

If NØUT = 2 plot of pressure at x = 0.0 and x = 1.0

If NØUT = 3 plot of pressure at x = 0.0, 1.0 and 0.5.

NCØMB determines if combustion nonlinearities are considered:

If NCØMB = 0 neglected.

If NCØMB = 1 included.

Next card (necessary only if plots are required): YHI, YLAB, ITICY

YHI is the maximum ordinate for pressure plots.

Note: the ordinate scales for pressure and amplitude plots are symmetric about zero.

YLAB is the interval for ordinate labeling for above plots.

ITICY is the number of ordinate tick marks for above plots.

Note: ITICY should be negative for pressure and amplitude plots to obtain centerline.

Next card (necessary only if plots are required): MDPLØT

MDPLØT determines if plots of individual modes are required:

If plot of J^{th} mode is required, punch "1" in the $5 \times J^{th}$ column.

If plot of J^{th} mode is not required, punch "0" in the $5 \times J^{th}$ column.

Next card (necessary only if plot of any mode amplitude is required): YHIMD, YLABMD, ITICMD

YHIMD is the maximum ordinate.

YLABMD is the interval for ordinate labelling.

ITICMD is the number of ordinate tick marks for mode plots.

Note: ITICMD should be negative to obtain centerline.

Remaining cards (NTERMS in number): J, AST, ACT

AST is the amplitude of the sine term of the J^{th} mode.

ACT is the amplitude of the cosine term of the J^{th} mode.

The comments in Section 3.2 on choosing AST to obtain a desired single-mode initial pressure disturbance apply here also.

Description of the Subroutines.

SUBRØUTINE PHICFS (NP, Z, CT, CZ). This subroutine performs the same function and is structurally the same as subroutine PHICFS described in Section 3.2.

SUBRØUTINE PRSVEL(AXLØC, VL, Y, P, VZGAS, VZPAR). This subroutine computes the pressure (P) and axial velocity perturbations (VZGAS and VZPAR) of the gas and particles at a given axial location (AXLØC) in the T-burner, using the supplied mode-amplitude functions and their derivatives (Y). The steady-state quantities at the given axial location are computed using subroutine STEADY, and VL represents the required vent effect. Pressure is computed from the second-order momentum equation and velocity is computed as the axial derivative of the velocity potential. The space-dependent coefficients (CØEF) of Φ_t and Φ_z are computed by subroutine PHICFS and are supplied through the common block BLK3.

SUBRØUTINE RHS (U,UP,UN, UNP). This subroutine is similar to subroutine RHS described in Section 3.2, except that in this case there are two additional dependent variables (UN) representing the real and imaginary parts of the fluctuating velocity through the vent. The equations for these variables (Equations

(76)) are solved simultaneously with the equations for the mode-amplitudes for the T-burner. The differential increments (UNP) of these variables needed for the Runge-Kutta integration are calculated by this subroutine. The calculation of the increments UP is similar to that in program SOLID2.

<u>SUBRØUTINE STEADY (X, UBAR, UPBAR, RHØP, DUBAR, DUPBAR)</u>. This subroutine, used for calculating the steady-state quantities, is same as that in Program TB1.

Besides the above subroutines, Program TB2 contains the following subroutines which are exactly the same as those used in Program SOLID2: (1) GRØWTH, (2) RESPNS, (3) GRAPHS, (4) MYAXIS, (5) MYLINE, (6) AXLAB, and (7) DENDEC. These subroutines have already been described in Section 3.2.

<u>Description of Output</u>. As in the case of Program SOLID2, there are two modes of output: (1) printed output and (2) plotted output. The printed output produced by Program TB2 consists of seven sections.

Section (1) is a restatement of the input from Program TB1. It includes the following information: (a) the propellant grain length (BETA), vent width (BETAV), radius-to-length ratio (RRL), velocity at the burning surface (UB), parameter (VL) indicating the vent effect, effective plug-flow vent length (EL), number of modes considered in the series, specific heat ratio of the pure gas (GAM) and (if particles are present) the specific heat ratio of the mixture (GAMMABAR); (b) information about the particles (if present); (c) the parameters which describe and identify each term in the series expansion; (d) the axial acoustic eigenvalues, B(J), for each term; (e) linear coefficients if NØUTCF = 1 or 2; and (f) nonlinear coefficients if NØUTCF = 2.

The other six sections of printed output and the plotted output are the same as described in Section 3.2 for Program SOLID2.

<u>Sample Case</u>. In this sample run, pressure-time histories are obtained for the T-burner considered in Section 4.1. The data generated by Program TB1 in Section 4.1 is used for the second part of the necessary input as described in this section. The same linear combustion response parameters (A,B,n, and Ω) as for the motor are used, and linear particle damping is considered. A step size of 0.025 is chosen, and TQUIT = 10.0. A pure 1L-mode initial disturbance of 7.5% pressure is assumed for which ACT = 0.0 and AST = - 0.0234625. Pressure maxima and minima are obtained at X = 0.0, hence NLØC = 1, and plots of the pressure disturbance at z = 0.0 only is desired, hence NØUT = 1. It is also desired to obtain plots of the growth of all of the mode-amplitude functions.

An input deck with these data is illustrated on the next page. The following pages present the printed output and the plotted output, generated by Program TB2 using this deck and the coefficients generated by Program TB1 in Section 4.2.

```
    0    0
TEST CASE FØR TB2
     0.025       0.0      10.0    1071.0       0.0
     5.996      0.58     0.575       4.2
    1    1    1    0
      0.10      0.05  -21
    1    1    1    1    1
      0.03      0.01  -31
    1 -.0234625       0.0
```

```
ENC BURNING IS PRESENT.

BETA = .10000

BETAV = .10000

R/L = .05071

U3 = .00198

VL = 1.0

EL =  .16600

NUMBER OF MODES = 5

GAMMA = 1.23

GAMMABAR = 1.176770


PARTICLE DIA (IN MICRONS) = 2.50      CM = .36      FREQ (IN HERTZ) = 1071.0

CHAMBER TEMP (IN DEG K) = 3525.0      SP = .68      RHOM (IN KG/CUBIC METER) = 4000.0

PARTICLE DRAG CONSTANT, K = 29.9186


NAME    J   L

1L      1   1
2L      2   2
3L      3   3
4L      4   4
5L      5   5


J        B(J)

1       3.14159
2       6.28319
3       9.42478
4      12.56637
5      15.70796
```

COEFFICIENTS FOR COMPUTATION OF WALL PRESSURE WAVEFORMS

J	Z	COEFFICIENTS IN SERIES FOR: TIME DERIVATIVE	AXIAL DERIVATIVE
1	0.000	1.0000000	0.0000000
2	0.000	0.0000000	0.0000000
3	0.000	1.0000000	0.0000000
4	0.000	0.0000000	0.0000000
5	0.000	1.0000000	0.0000000
6	0.000	0.0000000	0.0000000
7	0.000	1.0000000	0.0000000
8	0.000	0.0000000	0.0000000
9	0.000	1.0000000	0.0000000
10	0.000	0.0000000	0.0000000
1	1.000	-1.0000000	-.0000000
2	1.000	0.0000000	0.0000000
3	1.000	1.0000000	-.0000000
4	1.000	0.0000000	0.0000000
5	1.000	-1.0000000	-.0000000
6	1.000	0.0000000	0.0000000
7	1.000	1.0000000	.0000001
8	1.000	0.0000000	0.0000000
9	1.000	-1.0000000	.0000000
10	1.000	0.0000000	0.0000000
1	.500	.0000000	-3.1415927
2	.500	0.0000000	0.0000000
3	.500	-1.0000000	.0000000
4	.500	0.0000000	0.0000000
5	.500	-.0000000	9.4247780
6	.500	0.0000000	0.0000000
7	.500	1.0000000	.0000000
8	.500	0.0000000	0.0000000
9	.500	-.0000000	-15.7079633
10	.500	0.0000000	0.0000000

COMBUSTION PARAMETERS: A = 5.9960 B = .5600 EN = .575 OMEGA = 4.200

J	RESR	RESI
1	4.1401	.0926
2	.9605	-1.7016
3	.5013	-1.0872
4	.3777	-.8191
5	.3194	-.6694

LINEAR COMBUSTION RESPONSE.

LINEAR PARTICLE DAMPING.

INITIAL CONDITIONS ARE OF THE FORM:

U(I,J) = AC(J)*COS(FREQ*T) + AS(J)*SIN(FREQ*T)

J	FREQUENCY	AC(J)	AS(J)
1	2.63496206	0.00000000	-.02346250
2	2.63496206	-.02346250	0.00000000

THIS RUN PRODUCES PLOTTED OUTPUT.

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
0	0.00000	.07500	-.07050	.00000	0.00000	0.00000
1	.02500	.07460	-.07149	.00000	.00438	.00136
2	.05000	.07416	-.07153	.00000	.00826	.00412
3	.07500	.07343	-.07114	.00000	.01192	.00740
4	.10000	.07235	-.07030	.00000	.01546	.01084
5	.12500	.07089	-.06909	-.00000	.01891	.01430
6	.15000	.06905	-.06753	-.00001	.02224	.01773
7	.17500	.06686	-.06564	-.00002	.02546	.02107
8	.20000	.06433	-.06343	-.00004	.02854	.02431
9	.22500	.06150	-.06091	-.00006	.03147	.02742
10	.25000	.05837	-.05811	-.00010	.03423	.03039
11	.27500	.05500	-.05505	-.00015	.03683	.03320
12	.30000	.05139	-.05173	-.00021	.03926	.03585
13	.32500	.04759	-.04819	-.00028	.04150	.03833
14	.35000	.04362	-.04443	-.00036	.04356	.04063
15	.37500	.03950	-.04047	-.00046	.04544	.04275
16	.40000	.03524	-.03632	-.00056	.04712	.04469
17	.42500	.03088	-.03199	-.00069	.04862	.04644
18	.45000	.02641	-.02749	-.00082	.04992	.04800
19	.47500	.02186	-.02294	-.00097	.05102	.04937
20	.50000	.01723	-.01805	-.00112	.05190	.05053
21	.52500	.01255	-.01314	-.00129	.05257	.05145
22	.55000	.00782	-.00812	-.00146	.05300	.05221
23	.57500	.00307	-.00303	-.00164	.05319	.05271
24	.60000	-.00168	.00211	-.00183	.05314	.05298
25	.62500	-.00641	.00727	-.00201	.05283	.05301
26	.65000	-.01111	.01243	-.00218	.05227	.05278
27	.67500	-.01574	.01754	-.00235	.05145	.05230
28	.70000	-.02029	.02258	-.00250	.05038	.05157
29	.72500	-.02473	.02751	-.00264	.04906	.05058
30	.75000	-.02904	.03229	-.00275	.04753	.04935
31	.77500	-.03319	.03691	-.00284	.04572	.04788
32	.80000	-.03719	.04134	-.00289	.04372	.04618
33	.82500	-.04100	.04555	-.00291	.04151	.04426
34	.85000	-.04463	.04953	-.00289	.03913	.04213
35	.87500	-.04807	.05325	-.00283	.03657	.03982
36	.90000	-.05131	.05671	-.00273	.03385	.03732
37	.92500	-.05434	.05989	-.00259	.03098	.03467
38	.95000	-.05717	.06278	-.00241	.02799	.03186
39	.97500	-.05979	.06536	-.00220	.02487	.02891
40	1.00000	-.06218	.06764	-.00195	.02164	.02585
41	1.02500	-.06435	.06960	-.00167	.01832	.02266
42	1.05000	-.06629	.07122	-.00136	.01491	.01938
43	1.07500	-.06798	.07251	-.00104	.01143	.01601

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
44	1.10000	-.06942	.07345	-.00069	.00769	.01256
45	1.12500	-.07058	.07404	-.00035	.00431	.00905
46	1.15000	-.07146	.07426	.00001	.00070	.00549
47	1.17500	-.07203	.07413	.00035	-.00291	.00190
48	1.20000	-.07229	.07363	.00069	-.00652	-.00170
49	1.22500	-.07223	.07277	.00101	-.01010	-.00530
50	1.25000	-.07163	.07157	.00131	-.01363	-.00888
51	1.27500	-.07110	.07002	.00157	-.01709	-.01241
52	1.30000	-.07002	.06815	.00181	-.02046	-.01568
53	1.32500	-.06859	.06597	.00200	-.02372	-.01927
54	1.35000	-.06682	.06350	.00215	-.02687	-.02256
55	1.37500	-.06471	.06076	.00226	-.02988	-.02574
56	1.40000	-.06226	.05777	.00231	-.03274	-.02878
57	1.42500	-.05949	.05456	.00232	-.03545	-.03169
58	1.45000	-.05640	.05115	.00227	-.03798	-.03444
59	1.47500	-.05301	.04756	.00216	-.04034	-.03703
60	1.50000	-.04932	.04381	.00200	-.04252	-.03944
61	1.52500	-.04535	.03991	.00179	-.04452	-.04168
62	1.55000	-.04113	.03583	.00152	-.04632	-.04373
63	1.57500	-.03665	.03176	.00121	-.04791	-.04559
64	1.60000	-.03195	.02753	.00085	-.04931	-.04726
65	1.62500	-.02705	.02322	.00046	-.05049	-.04871
66	1.65000	-.02197	.01885	.00003	-.05146	-.04997
67	1.67500	-.01674	.01443	-.00043	-.05220	-.05100
68	1.70000	-.01138	.00997	-.00091	-.05272	-.05182
69	1.72500	-.00594	.00548	-.00141	-.05300	-.05241
70	1.75000	-.00044	.00100	-.00191	-.05305	-.05276
71	1.77500	.00508	-.00348	-.00240	-.05286	-.05289
72	1.80000	.01058	-.00793	-.00288	-.05242	-.05278
73	1.82500	.01602	-.01233	-.00334	-.05175	-.05242
74	1.85000	.02138	-.01667	-.00377	-.05084	-.05183
75	1.87500	.02660	-.02093	-.00415	-.04970	-.05100
76	1.90000	.03167	-.02511	-.00449	-.04833	-.04994
77	1.92500	.03655	-.02917	-.00476	-.04673	-.04865
78	1.95000	.04122	-.03311	-.00497	-.04492	-.04713
79	1.97500	.04564	-.03692	-.00511	-.04290	-.04540
80	2.00000	.04979	-.04059	-.00518	-.04068	-.04345
81	2.02500	.05366	-.04411	-.00516	-.03827	-.04131
82	2.05000	.05722	-.04748	-.00506	-.03569	-.03897
83	2.07500	.06047	-.05068	-.00488	-.03294	-.03645
84	2.10000	.06339	-.05370	-.00461	-.03003	-.03376
85	2.12500	.06597	-.05654	-.00428	-.02697	-.03091
86	2.15000	.06821	-.05919	-.00387	-.02378	-.02791
87	2.17500	.07010	-.06164	-.00339	-.02048	-.02478
88	2.20000	.07162	-.06388	-.00286	-.01707	-.02152
89	2.22500	.07279	-.06589	-.00228	-.01358	-.01815
90	2.25000	.07360	-.06767	-.00167	-.01001	-.01470
91	2.27500	.07405	-.06920	-.00103	-.00639	-.01117

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
92	2.30000	.07415	-.07047	-.00038	-.00274	-.00758
93	2.32500	.07389	-.07145	.00028	.00093	-.00395
94	2.35000	.07329	-.07214	.00092	.00459	-.00030
95	2.37500	.07235	-.07253	.00153	.00822	.00335
96	2.40000	.07110	-.07260	.00211	.01180	.00698
97	2.42500	.06953	-.07234	.00265	.01532	.01057
98	2.45000	.06767	-.07173	.00313	.01876	.01410
99	2.47500	.06553	-.07077	.00354	.02209	.01755
100	2.50000	.06313	-.06945	.00387	.02531	.02091
101	2.52500	.06049	-.06777	.00413	.02839	.02415
102	2.55000	.05762	-.06572	.00429	.03132	.02727
103	2.57500	.05455	-.06330	.00437	.03410	.03024
104	2.60000	.05129	-.06051	.00436	.03671	.03307
105	2.62500	.04786	-.05735	.00426	.03915	.03573
106	2.65000	.04428	-.05384	.00406	.04140	.03822
107	2.67500	.04056	-.04999	.00378	.04346	.04053
108	2.70000	.03672	-.04580	.00341	.04533	.04265
109	2.72500	.03278	-.04130	.00297	.04700	.04458
110	2.75000	.02874	-.03650	.00246	.04846	.04632
111	2.77500	.02463	-.03145	.00188	.04972	.04785
112	2.80000	.02046	-.02615	.00125	.05076	.04917
113	2.82500	.01623	-.02068	.00057	.05159	.05028
114	2.85000	.01197	-.01504	-.00014	.05220	.05118
115	2.87500	.00770	-.00928	-.00087	.05258	.05186
116	2.90000	.00341	-.00345	-.00162	.05275	.05232
117	2.92500	-.00087	.00242	-.00236	.05269	.05256
118	2.95000	-.00514	.00827	-.00309	.05240	.05257
119	2.97500	-.00936	.01406	-.00379	.05189	.05236
120	3.00000	-.01355	.01975	-.00445	.05115	.05193
121	3.02500	-.01767	.02529	-.00506	.05019	.05127
122	3.05000	-.02173	.03066	-.00561	.04901	.05038
123	3.07500	-.02570	.03580	-.00608	.04761	.04928
124	3.10000	-.02958	.04070	-.00646	.04599	.04795
125	3.12500	-.03336	.04532	-.00675	.04416	.04641
126	3.15000	-.03703	.04964	-.00694	.04213	.04465
127	3.17500	-.04058	.05364	-.00701	.03989	.04269
128	3.20000	-.04400	.05731	-.00698	.03745	.04052
129	3.22500	-.04728	.06062	-.00682	.03483	.03815
130	3.25000	-.05042	.06357	-.00655	.03203	.03560
131	3.27500	-.05340	.06616	-.00617	.02907	.03287
132	3.30000	-.05622	.06838	-.00563	.02594	.02996
133	3.32500	-.05886	.07023	-.00509	.02268	.02690
134	3.35000	-.06132	.07170	-.00441	.01929	.02369
135	3.37500	-.06358	.07281	-.00365	.01579	.02035
136	3.40000	-.06562	.07356	-.00282	.01221	.01690
137	3.42500	-.06744	.07395	-.00195	.00855	.01336
138	3.45000	-.06903	.07399	-.00105	.00485	.00974
139	3.47500	-.07036	.07369	-.00014	.00112	.00607

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
140	3.50000	-.07143	.07306	.00077	-.00260	.00236
141	3.52500	-.07221	.07211	.00166	-.00631	-.00135
142	3.55000	-.07269	.07086	.00250	-.00997	-.00505
143	3.57500	-.07286	.06932	.00328	-.01357	-.00871
144	3.60000	-.07270	.06750	.00399	-.01708	-.01232
145	3.62500	-.07219	.06542	.00461	-.02049	-.01584
146	3.65000	-.07132	.06310	.00513	-.02377	-.01927
147	3.67500	-.07008	.06055	.00554	-.02692	-.02259
148	3.70000	-.06845	.05779	.00583	-.02992	-.02578
149	3.72500	-.06642	.05484	.00600	-.03276	-.02882
150	3.75000	-.06399	.05171	.00605	-.03543	-.03170
151	3.77500	-.06115	.04842	.00597	-.03792	-.03442
152	3.80000	-.05790	.04498	.00577	-.04022	-.03697
153	3.82500	-.05425	.04141	.00546	-.04234	-.03933
154	3.85000	-.05020	.03772	.00504	-.04426	-.04151
155	3.87500	-.04576	.03394	.00451	-.04598	-.04349
156	3.90000	-.04099	.03006	.00390	-.04750	-.04528
157	3.92500	-.03588	.02610	.00320	-.04882	-.04687
158	3.95000	-.03048	.02209	.00243	-.04993	-.04825
159	3.97500	-.02482	.01802	.00160	-.05084	-.04943
160	4.00000	-.01896	.01392	.00073	-.05154	-.05041
161	4.02500	-.01294	.00979	-.00018	-.05203	-.05116
162	4.05000	-.00680	.00566	-.00110	-.05230	-.05174
163	4.07500	-.00062	.00153	-.00203	-.05237	-.05208
164	4.10000	.00556	-.00260	-.00295	-.05223	-.05222
165	4.12500	.01169	-.00669	-.00385	-.05187	-.05215
166	4.15000	.01771	-.01075	-.00471	-.05130	-.05186
167	4.17500	.02357	-.01476	-.00551	-.05052	-.05137
168	4.20000	.02922	-.01872	-.00625	-.04952	-.05065
169	4.22500	.03464	-.02261	-.00691	-.04831	-.04973
170	4.25000	.03977	-.02643	-.00747	-.04689	-.04859
171	4.27500	.04459	-.03017	-.00793	-.04525	-.04724
172	4.30000	.04908	-.03381	-.00826	-.04341	-.04568
173	4.32500	.05321	-.03736	-.00846	-.04135	-.04390
174	4.35000	.05698	-.04080	-.00853	-.03908	-.04191
175	4.37500	.06036	-.04413	-.00846	-.03661	-.03972
176	4.40000	.06337	-.04734	-.00823	-.03395	-.03732
177	4.42500	.06598	-.05041	-.00787	-.03109	-.03472
178	4.45000	.06821	-.05334	-.00736	-.02806	-.03194
179	4.47500	.07006	-.05612	-.00671	-.02486	-.02897
180	4.50000	.07153	-.05873	-.00594	-.02152	-.02584
181	4.52500	.07263	-.06117	-.00506	-.01804	-.02255
182	4.55000	.07337	-.06342	-.00409	-.01445	-.01912
183	4.57500	.07376	-.06548	-.00304	-.01077	-.01558
184	4.60000	.07380	-.06732	-.00194	-.00702	-.01195
185	4.62500	.07351	-.06893	-.00080	-.00324	-.00824
186	4.65000	.07290	-.07030	.00034	.00056	-.00449
187	4.67500	.07198	-.07141	.00146	.00434	-.00071

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
188	4.70000	.07077	-.07226	.00254	.00806	.00306
189	4.72500	.06928	-.07280	.00356	.01176	.00680
190	4.75000	.06753	-.07304	.00448	.01536	.01048
191	4.77500	.06553	-.07295	.00531	.01884	.01409
192	4.80000	.06329	-.07251	.00601	.02220	.01760
193	4.82500	.06084	-.07171	.00658	.02542	.02099
194	4.85000	.05818	-.07051	.00700	.02848	.02425
195	4.87500	.05534	-.06890	.00728	.03138	.02735
196	4.90000	.05233	-.06686	.00740	.03410	.03030
197	4.92500	.04916	-.06439	.00738	.03664	.03307
198	4.95000	.04584	-.06147	.00721	.03899	.03567
199	4.97500	.04240	-.05810	.00690	.04115	.03808
200	5.00000	.03885	-.05428	.00645	.04311	.04030
201	5.02500	.03519	-.05002	.00589	.04488	.04233
202	5.05000	.03144	-.04535	.00522	.04646	.04417
203	5.07500	.02761	-.04027	.00445	.04784	.04581
204	5.10000	.02372	-.03484	.00359	.04902	.04725
205	5.12500	.01979	-.02909	.00267	.05000	.04850
206	5.15000	.01581	-.02308	.00169	.05079	.04955
207	5.17500	.01180	-.01685	.00067	.05137	.05040
208	5.20000	.00778	-.01047	-.00038	.05176	.05106
209	5.22500	.00376	-.00401	-.00145	.05195	.05151
210	5.25000	-.00025	.00247	-.00251	.05194	.05177
211	5.27500	-.00424	.00890	-.00356	.05173	.05182
212	5.30000	-.00821	.01524	-.00458	.05131	.05168
213	5.32500	-.01213	.02140	-.00555	.05070	.05133
214	5.35000	-.01601	.02735	-.00646	.04988	.05079
215	5.37500	-.01983	.03303	-.00728	.04885	.05003
216	5.40000	-.02359	.03840	-.00802	.04762	.04906
217	5.42500	-.02728	.04343	-.00864	.04618	.04791
218	5.45000	-.03090	.04810	-.00914	.04452	.04654
219	5.47500	-.03443	.05238	-.00950	.04265	.04495
220	5.50000	-.03788	.05627	-.00970	.04057	.04315
221	5.52500	-.04122	.05975	-.00974	.03827	.04114
222	5.55000	-.04447	.06283	-.00961	.03575	.03891
223	5.57500	-.04759	.06550	-.00932	.03304	.03647
224	5.60000	-.05060	.06778	-.00884	.03012	.03382
225	5.62500	-.05347	.06967	-.00821	.02701	.03097
226	5.65000	-.05620	.07117	-.00741	.02373	.02793
227	5.67500	-.05877	.07230	-.00647	.02029	.02472
228	5.70000	-.06118	.07303	-.00540	.01671	.02134
229	5.72500	-.06340	.07350	-.00423	.01302	.01783
230	5.75000	-.06544	.07359	-.00297	.00925	.01419
231	5.77500	-.06727	.07335	-.00167	.00542	.01046
232	5.80000	-.06889	.07279	-.00034	.00156	.00667
233	5.82500	-.07027	.07194	.00099	-.00230	.00284
234	5.85000	-.07141	.07080	.00227	-.00613	-.00100
235	5.87500	-.07228	.06939	.00350	-.00989	-.00482

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
236	5.90000	-.07287	.06771	.00463	-.01357	-.00859
237	5.92500	-.07315	.06580	.00564	-.01714	-.01228
238	5.95000	-.07310	.06365	.00652	-.02058	-.01587
239	5.97500	-.07270	.06130	.00725	-.02387	-.01934
240	6.00000	-.07192	.05874	.00782	-.02700	-.02267
241	6.02500	-.07073	.05600	.00821	-.02996	-.02584
242	6.05000	-.06911	.05310	.00843	-.03273	-.02885
243	6.07500	-.06704	.05004	.00848	-.03532	-.03168
244	6.10000	-.06449	.04684	.00835	-.03772	-.03433
245	6.12500	-.06146	.04351	.00807	-.03993	-.03679
246	6.15000	-.05794	.04007	.00764	-.04194	-.03906
247	6.17500	-.05392	.03652	.00706	-.04376	-.04114
248	6.20000	-.04943	.03289	.00637	-.04539	-.04303
249	6.22500	-.04448	.02917	.00556	-.04682	-.04472
250	6.25000	-.03911	.02539	.00466	-.04807	-.04622
251	6.27500	-.03335	.02156	.00369	-.04912	-.04753
252	6.30000	-.02727	.01768	.00264	-.04999	-.04865
253	6.32500	-.02092	.01377	.00154	-.05066	-.04958
254	6.35000	-.01436	.00984	.00041	-.05115	-.05032
255	6.37500	-.00768	.00591	-.00074	-.05145	-.05087
256	6.40000	-.00095	.00198	-.00191	-.05156	-.05124
257	6.42500	.00576	-.00194	-.00307	-.05147	-.05141
258	6.45000	.01238	-.00583	-.00421	-.05120	-.05139
259	6.47500	.01883	-.00968	-.00531	-.05074	-.05118
260	6.50000	.02506	-.01349	-.00636	-.05008	-.05078
261	6.52500	.03100	-.01726	-.00734	-.04923	-.05019
262	6.55000	.03662	-.02097	-.00823	-.04817	-.04940
263	6.57500	.04188	-.02461	-.00901	-.04691	-.04841
264	6.60000	.04674	-.02820	-.00967	-.04544	-.04721
265	6.62500	.05119	-.03171	-.01019	-.04376	-.04581
266	6.65000	.05522	-.03515	-.01054	-.04186	-.04420
267	6.67500	.05882	-.03850	-.01072	-.03974	-.04237
268	6.70000	.06200	-.04176	-.01072	-.03740	-.04032
269	6.72500	.06476	-.04492	-.01052	-.03483	-.03805
270	6.75000	.06711	-.04798	-.01013	-.03205	-.03556
271	6.77500	.06906	-.05092	-.00954	-.02906	-.03285
272	6.80000	.07063	-.05373	-.00877	-.02587	-.02993
273	6.82500	.07183	-.05641	-.00782	-.02249	-.02681
274	6.85000	.07267	-.05893	-.00671	-.01896	-.02351
275	6.87500	.07316	-.06130	-.00546	-.01528	-.02004
276	6.90000	.07332	-.06349	-.00411	-.01150	-.01643
277	6.92500	.07316	-.06550	-.00267	-.00764	-.01270
278	6.95000	.07269	-.06731	-.00119	-.00374	-.00889
279	6.97500	.07193	-.06891	.00030	.00018	-.00502
280	7.00000	.07088	-.07029	.00176	.00408	-.00112
281	7.02500	.06956	-.07143	.00317	.00793	.00276
282	7.05000	.06798	-.07231	.00449	.01169	.00660
283	7.07500	.06616	-.07291	.00569	.01535	.01037

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
284	7.10000	.06412	-.07321	.00674	.01887	.01405
285	7.12500	.06186	-.07317	.00763	.02224	.01760
286	7.15000	.05940	-.07278	.00834	.02544	.02101
287	7.17500	.05677	-.07200	.00887	.02846	.02425
288	7.20000	.05396	-.07079	.00919	.03130	.02733
289	7.22500	.05101	-.06913	.00933	.03394	.03022
290	7.25000	.04791	-.06693	.00928	.03639	.03293
291	7.27500	.04469	-.06433	.00904	.03865	.03544
292	7.30000	.04135	-.06115	.00865	.04071	.03776
293	7.32500	.03791	-.05745	.00809	.04258	.03989
294	7.35000	.03437	-.05322	.00741	.04427	.04183
295	7.37500	.03076	-.04847	.00660	.04576	.04358
296	7.40000	.02707	-.04324	.00566	.04708	.04515
297	7.42500	.02332	-.03756	.00458	.04820	.04652
298	7.45000	.01953	-.03149	.00360	.04915	.04771
299	7.47500	.01569	-.02509	.00247	.04991	.04872
300	7.50000	.01184	-.01843	.00129	.05049	.04955
301	7.52500	.00797	-.01160	.00007	.05089	.05019
302	7.55000	.00411	-.00466	-.00116	.05111	.05065
303	7.57500	.00026	.00228	-.00239	.05115	.05093
304	7.60000	-.00358	.00915	-.00362	.05101	.05103
305	7.62500	-.00738	.01587	-.00482	.05068	.05095
306	7.65000	-.01114	.02237	-.00599	.05017	.05069
307	7.67500	-.01486	.02857	-.00709	.04947	.05024
308	7.70000	-.01852	.03444	-.00812	.04858	.04960
309	7.72500	-.02213	.03993	-.00905	.04750	.04877
310	7.75000	-.02569	.04501	-.00986	.04621	.04775
311	7.77500	-.02917	.04965	-.01053	.04471	.04652
312	7.80000	-.03260	.05385	-.01105	.04300	.04509
313	7.82500	-.03595	.05760	-.01138	.04106	.04344
314	7.85000	-.03922	.06091	-.01153	.03889	.04157
315	7.87500	-.04240	.06378	-.01146	.03649	.03948
316	7.90000	-.04550	.06624	-.01118	.03386	.03716
317	7.92500	-.04849	.06829	-.01069	.03100	.03460
318	7.95000	-.05136	.06995	-.00998	.02793	.03182
319	7.97500	-.05411	.07124	-.00907	.02465	.02882
320	8.00000	-.05673	.07217	-.00797	.02118	.02562
321	8.02500	-.05920	.07276	-.00670	.01754	.02222
322	8.05000	-.06151	.07302	-.00529	.01378	.01866
323	8.07500	-.06365	.07296	-.00378	.00991	.01495
324	8.10000	-.06562	.07260	-.00219	.00597	.01114
325	8.12500	-.06739	.07193	-.00057	.00200	.00725
326	8.15000	-.06897	.07099	.00104	-.00196	.00331
327	8.17500	-.07032	.06978	.00261	-.00589	-.00063
328	8.20000	-.07145	.06831	.00409	-.00973	-.00454
329	8.22500	-.07232	.06659	.00546	-.01347	-.00839
330	8.25000	-.07291	.06465	.00668	-.01708	-.01215
331	8.27500	-.07320	.06249	.00773	-.02053	-.01578

STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
332	8.30000	-.07316	.06014	.00859	-.02381	-.01927
333	8.32500	-.07275	.05760	.00925	-.02691	-.02260
334	8.35000	-.07193	.05490	.00970	-.02982	-.02575
335	8.37500	-.07067	.05204	.00994	-.03252	-.02871
336	8.40000	-.06893	.04905	.00997	-.03503	-.03149
337	8.42500	-.06668	.04592	.00981	-.03735	-.03406
338	8.45000	-.06388	.04268	.00947	-.03947	-.03644
339	8.47500	-.06053	.03934	.00895	-.04140	-.03863
340	8.50000	-.05662	.03589	.00829	-.04314	-.04063
341	8.52500	-.05214	.03237	.00750	-.04470	-.04244
342	8.55000	-.04713	.02876	.00659	-.04608	-.04406
343	8.57500	-.04161	.02510	.00559	-.04727	-.04550
344	8.60000	-.03563	.02137	.00450	-.04829	-.04676
345	8.62500	-.02926	.01761	.00335	-.04914	-.04784
346	8.65000	-.02257	.01382	.00215	-.04981	-.04875
347	8.67500	-.01565	.01001	.00091	-.05030	-.04948
348	8.70000	-.00858	.00620	-.00036	-.05062	-.05003
349	8.72500	-.00146	.00239	-.00165	-.05077	-.05041
350	8.75000	.00562	-.00140	-.00294	-.05074	-.05062
351	8.77500	.01256	-.00515	-.00421	-.05053	-.05065
352	8.80000	.01932	-.00888	-.00546	-.05015	-.05050
353	8.82500	.02579	-.01256	-.00667	-.04960	-.05018
354	8.85000	.03191	-.01619	-.00781	-.04886	-.04968
355	8.87500	.03764	-.01977	-.00886	-.04793	-.04900
356	8.90000	.04294	-.02329	-.00981	-.04681	-.04813
357	8.92500	.04779	-.02676	-.01063	-.04548	-.04707
358	8.95000	.05219	-.03017	-.01130	-.04394	-.04581
359	8.97500	.05611	-.03351	-.01179	-.04219	-.04434
360	9.00000	.05957	-.03679	-.01208	-.04020	-.04264
361	9.02500	.06259	-.03999	-.01216	-.03797	-.04073
362	9.05000	.06518	-.04311	-.01202	-.03551	-.03858
363	9.07500	.06735	-.04614	-.01164	-.03280	-.03619
364	9.10000	.06913	-.04906	-.01103	-.02986	-.03356
365	9.12500	.07053	-.05188	-.01020	-.02670	-.03070
366	9.15000	.07157	-.05457	-.00914	-.02332	-.02762
367	9.17500	.07227	-.05712	-.00789	-.01975	-.02432
368	9.20000	.07265	-.05953	-.00648	-.01603	-.02083
369	9.22500	.07270	-.06179	-.00493	-.01218	-.01718
370	9.25000	.07245	-.06383	-.00327	-.00823	-.01339
371	9.27500	.07191	-.06579	-.00156	-.00424	-.00950
372	9.30000	.07109	-.06752	.00016	-.00023	-.00554
373	9.32500	.06999	-.06906	.00186	.00376	-.00156
374	9.35000	.06864	-.07033	.00349	.00768	.00240
375	9.37500	.06704	-.07143	.00501	.01150	.00632
376	9.40000	.06520	-.07232	.00639	.01519	.01015
377	9.42500	.06316	-.07290	.00760	.01873	.01386
378	9.45000	.06091	-.07317	.00861	.02209	.01743
379	9.47500	.05847	-.07309	.00941	.02527	.02084

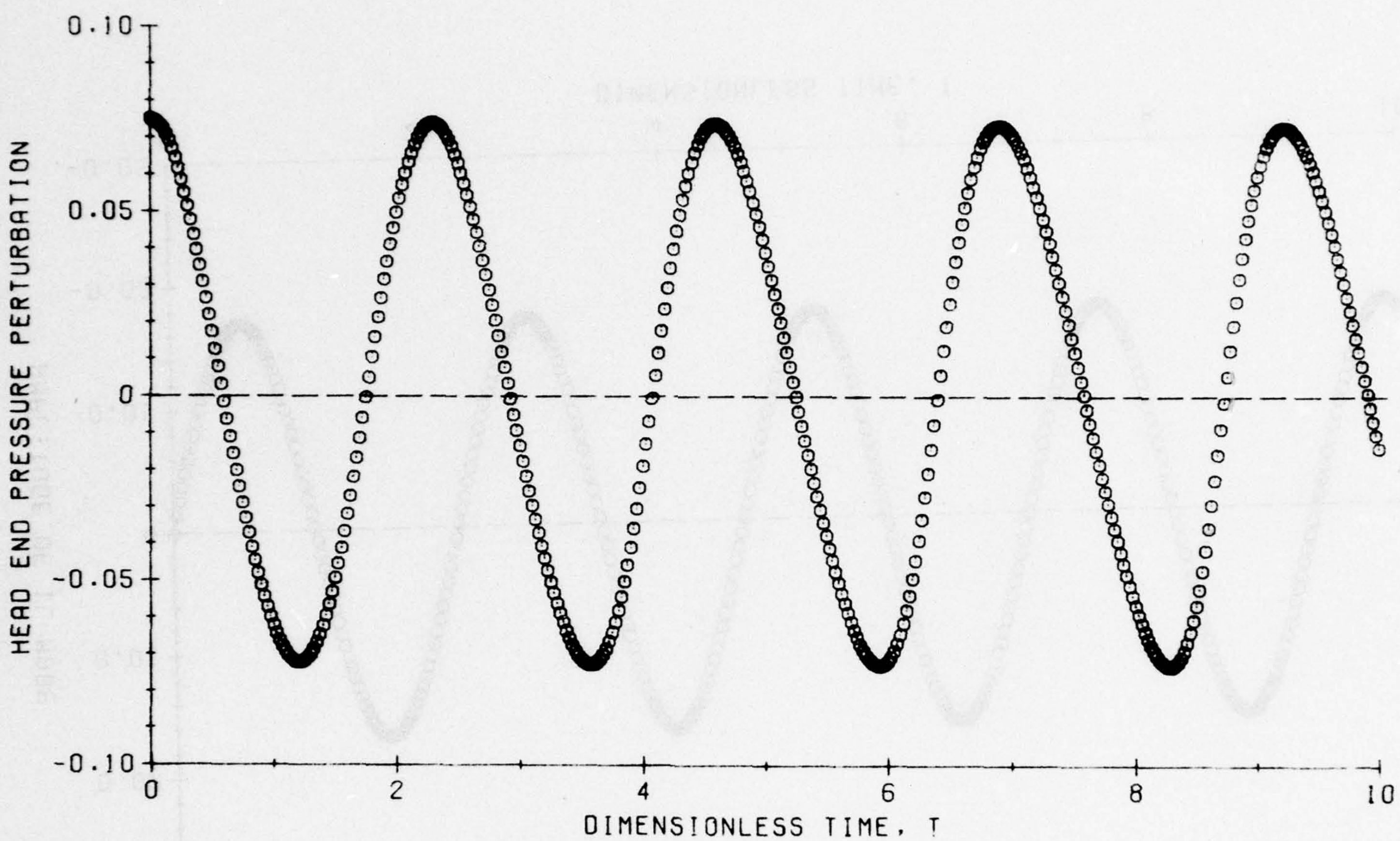
STEP	TIME	PRESSURE AT Z=0.0	PRESSURE AT Z=1.0	PRESSURE AT Z=0.5	GAS VEL AT Z=0.5	PAR VEL AT Z=0.5
380	9.50000	.05587	-.07264	.00999	.02825	.02408
381	9.52500	.05311	-.07176	.01035	.03103	.02712
382	9.55000	.05021	-.07041	.01049	.03361	.02996
383	9.57500	.04718	-.06856	.01042	.03599	.03261
384	9.60000	.04403	-.06616	.01015	.03817	.03506
385	9.62500	.04078	-.06319	.00970	.04016	.03731
386	9.65000	.03742	-.05964	.00908	.04197	.03937
387	9.67500	.03398	-.05543	.00832	.04359	.04125
388	9.70000	.03046	-.05075	.00744	.04504	.04294
389	9.72500	.02686	-.04546	.00646	.04631	.04444
390	9.75000	.02321	-.03966	.00538	.04741	.04578
391	9.77500	.01951	-.03340	.00424	.04833	.04693
392	9.80000	.01577	-.02676	.00303	.04909	.04792
393	9.82500	.01201	-.01932	.00178	.04967	.04873
394	9.85000	.00824	-.01268	.00049	.05009	.04936
395	9.87500	.00447	-.00543	-.00082	.05033	.04985
396	9.90000	.00072	.00182	-.00214	.05041	.05015
397	9.92500	-.00301	.00897	-.00347	.05032	.05029
398	9.95000	-.00670	.01595	-.00478	.05006	.05026
399	9.97500	-.01036	.02265	-.00606	.04964	.05006
400	10.00000	-.01396	.02902	-.00729	.04903	.04968
401	10.02500	-.01752	.03500	-.00845	.04825	.04914

```
FRESSURE MAXIMA AND MINIMA AT:   Z =  0.00
VALUES COMPUTED:     8

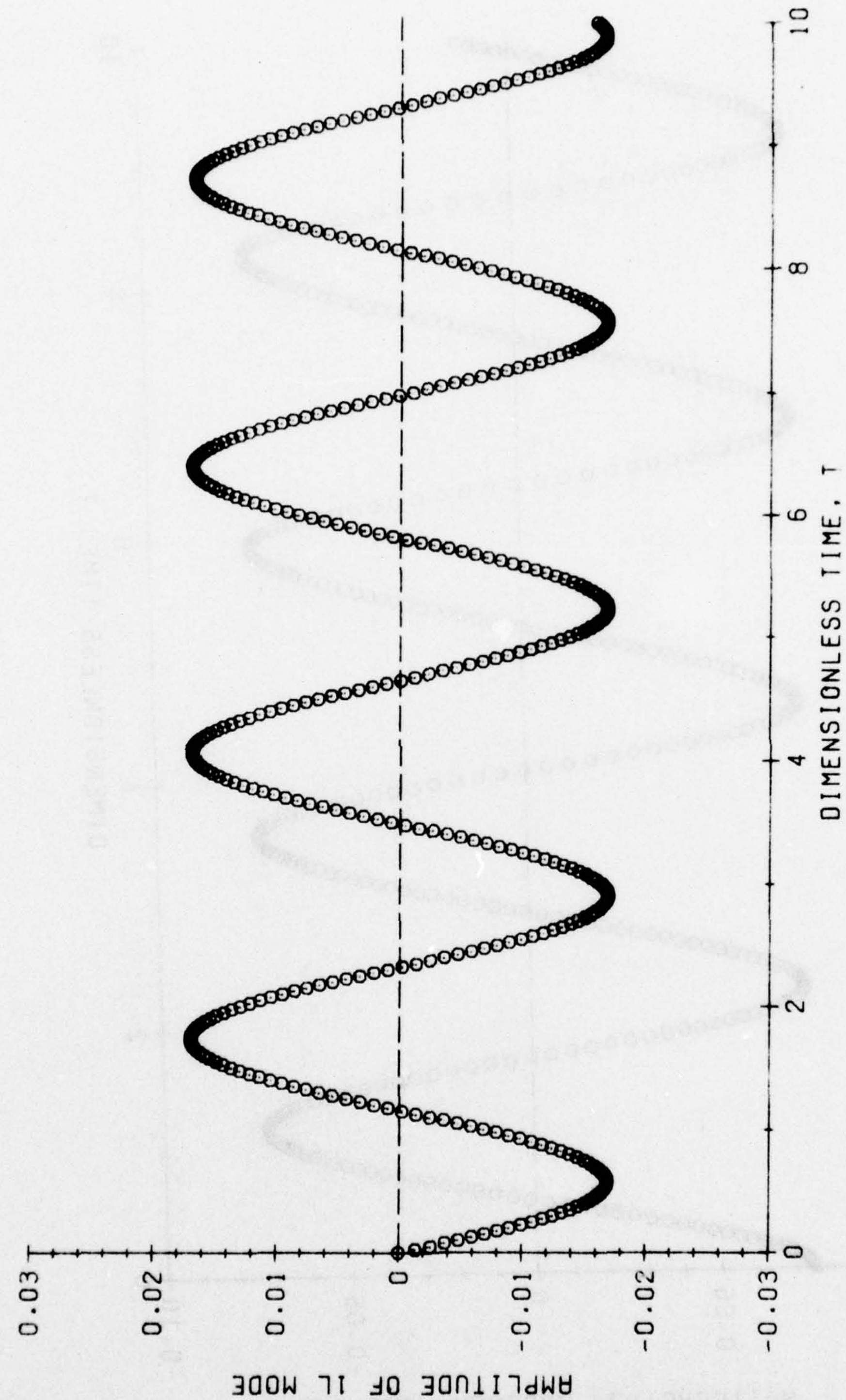
     -.072308     .074155    -.072859     .073820    -.073171     .073325    -.073228     .072717
     1.207692    2.294207    3.575259    4.590680    5.933782    6.899987    8.284337    9.217136
```

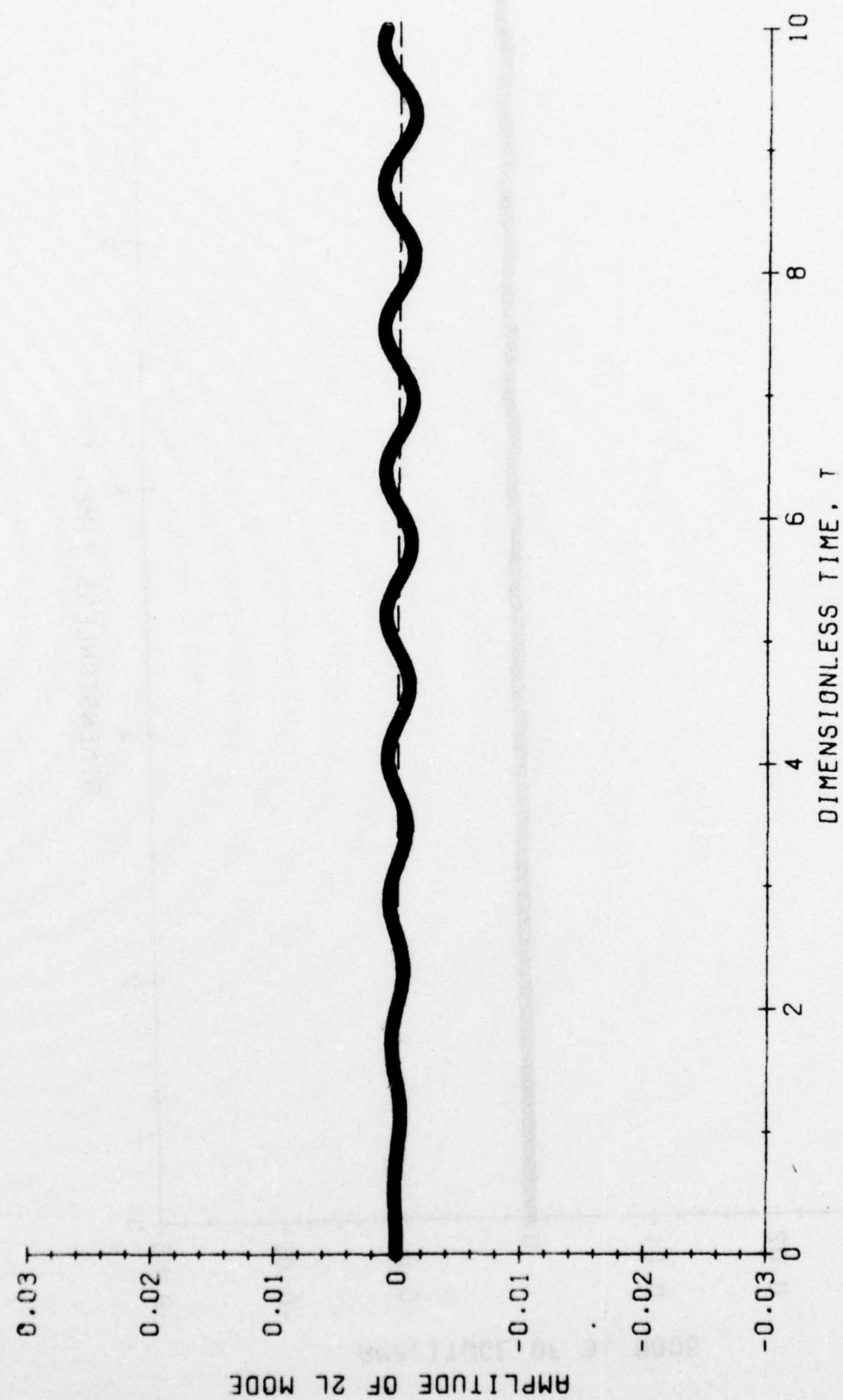
PRESSURE GROWTH RATE AND FREQUENCY.
TOTAL NUMBER OF CYCLES: 3 .

-4.213217	-6.248792	-7.694705
932.734549	927.550936	924.412032
3.442443	5.745333	8.058561

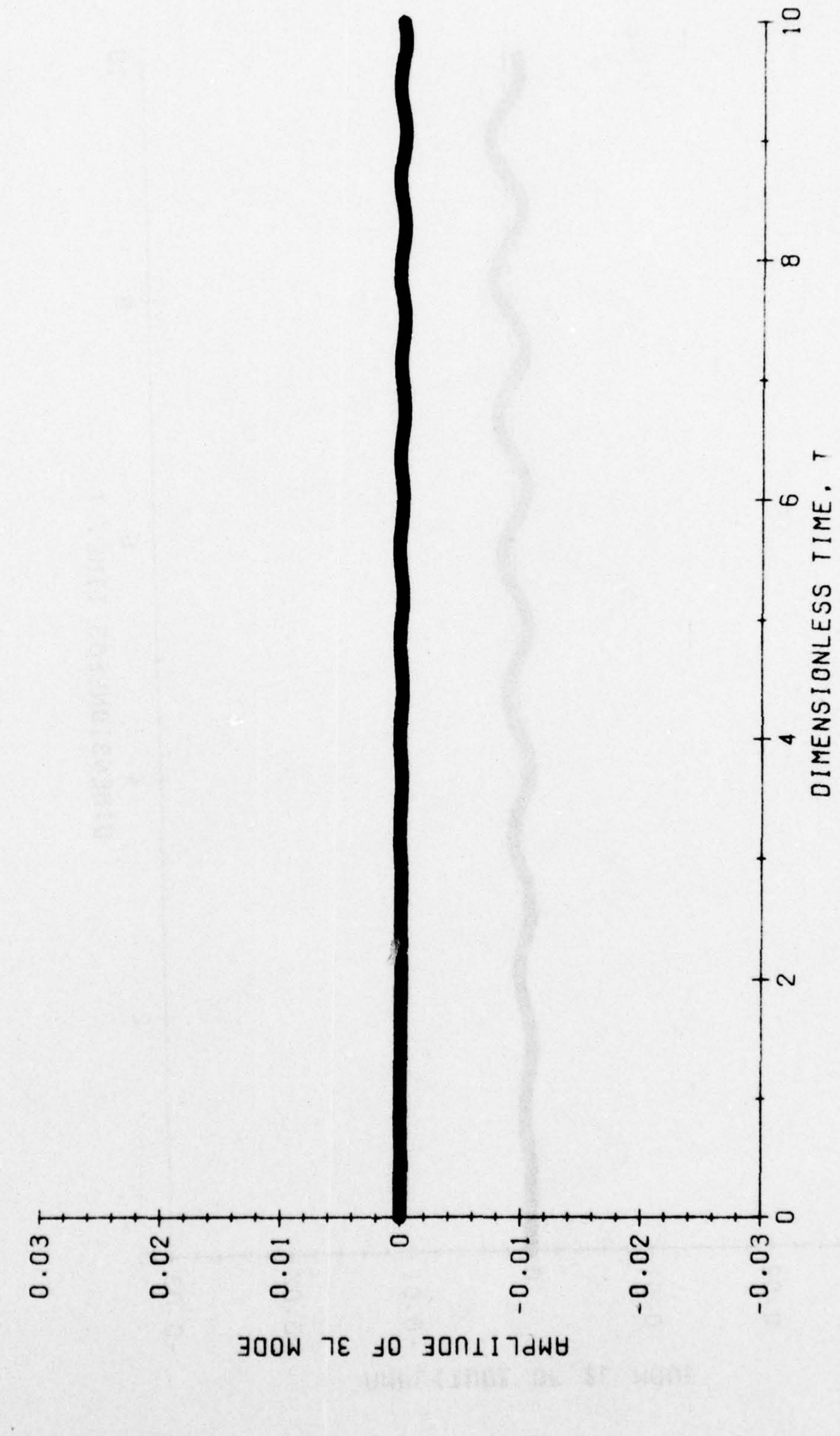


HEAD END PRESSURE PERTURBATION
0.10
0.05
0
-0.05
-0.10
0
2
4
6
8
10
DIMENSIONLESS TIME, T


AMPLITUDE OF IL MODE
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
0
2
4
6
8
10
DIMENSIONLESS TIME, T



AMPLITUDE OF 2L MODE
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
0
2
4
6
8
10
DIMENSIONLESS TIME, τ


AMPLITUDE OF 3L MODE
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0.02
0.01
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-0.01
-0.02
-0.03
0
2
4
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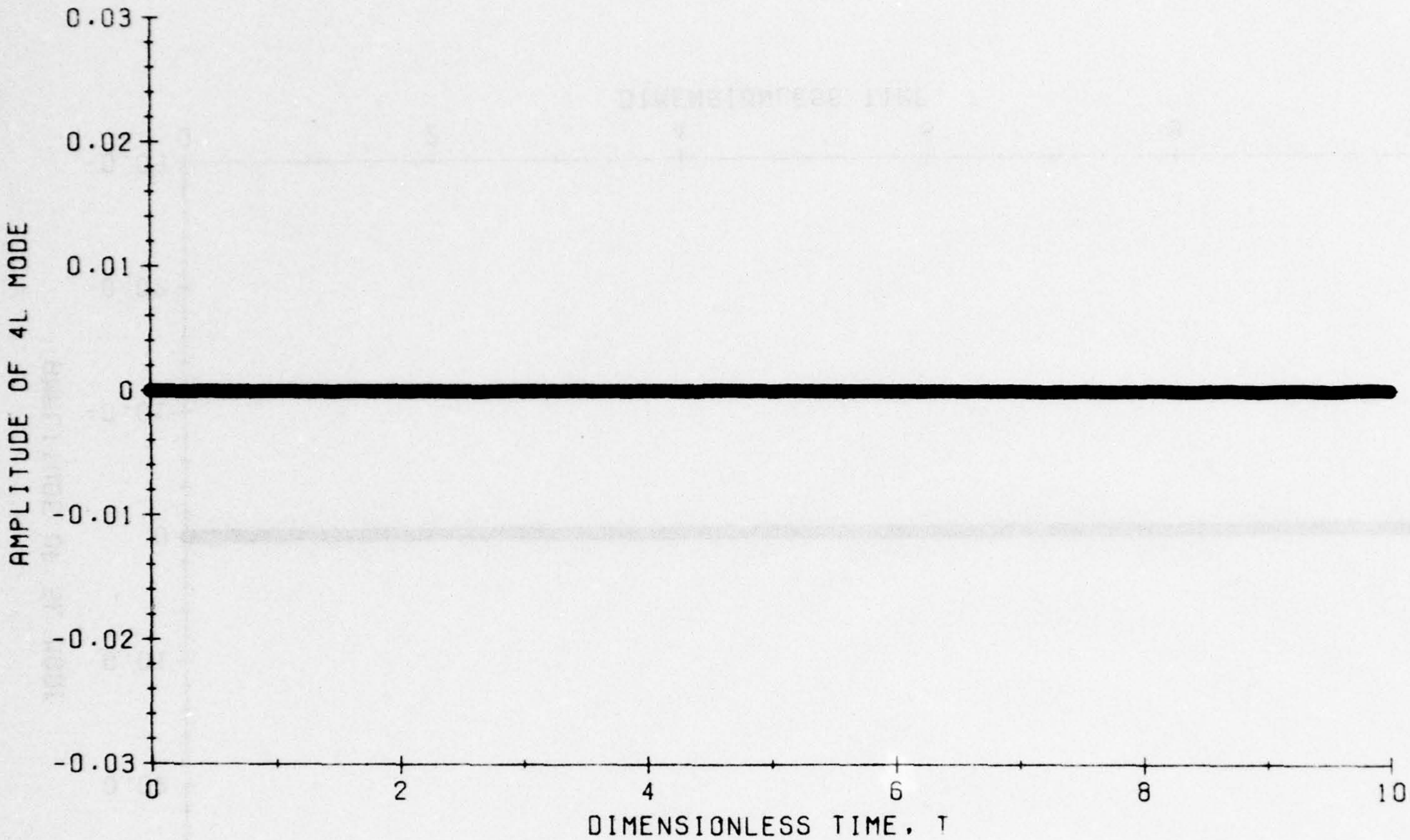
8
10
DIMENSIONLESS TIME, τ


AMPLITUDE OF 4L MODE
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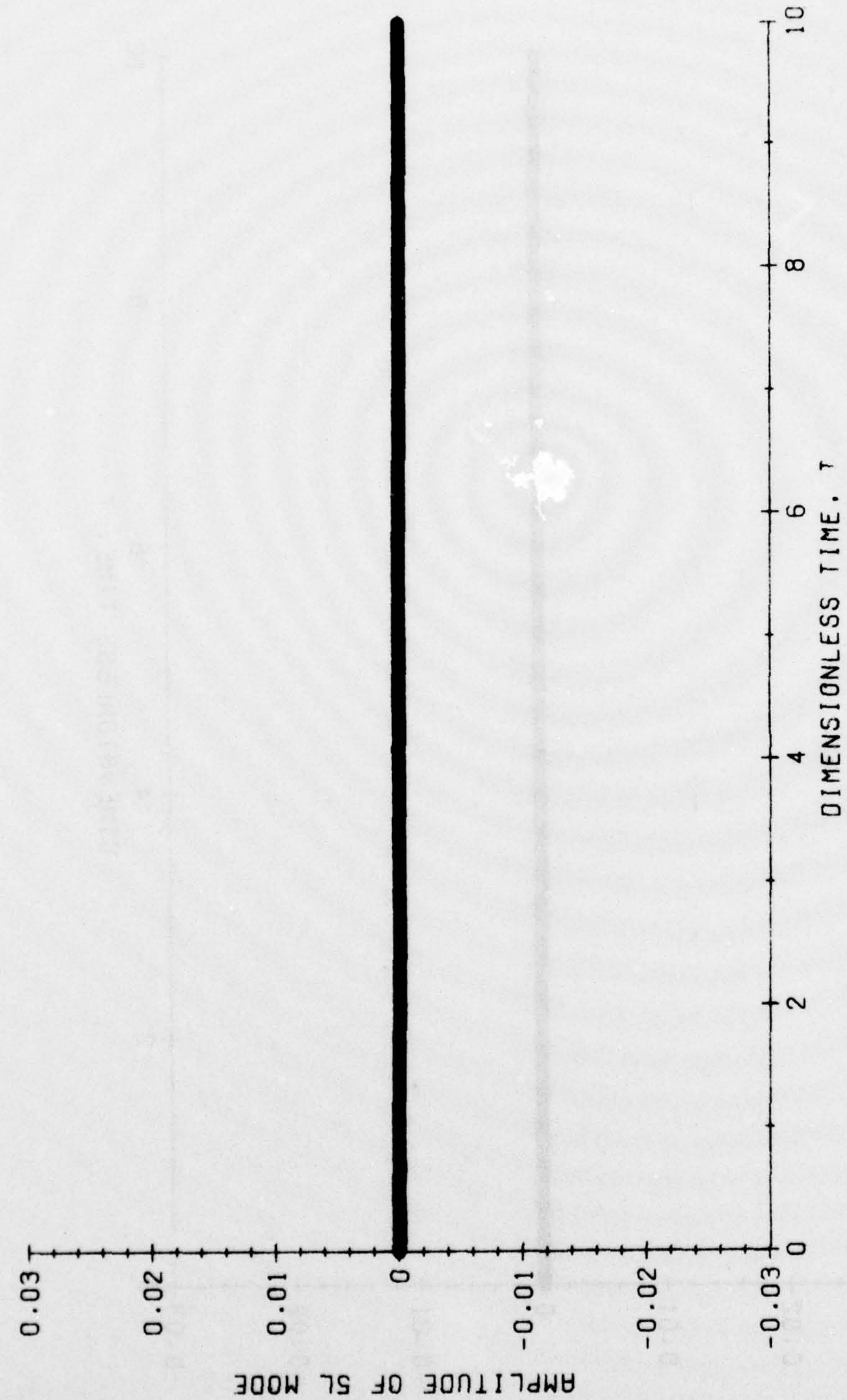
0.02
0.01
0
-0.01
-0.02
-0.03
0
2
4
6
8
10
DIMENSIONLESS TIME, T


AMPLITUDE OF 5L MODE
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0.02
0.01
0
-0.01
-0.02
-0.03
DIMENSIONLESS TIME, τ
0
2
4
6
8
10

FORTRAN Source Code.

```
      PROGRAM TB2(INPUT,OUTPUT,DATA,
     1            TAPE5=INPUT,TAPE6=OUTPUT,TAPE9=DATA)
C
C
C     *************** PROGRAM TB2 ******************************
C
C
C          THIS PROGRAM INTEGRATES THE SYSTEM OF DIFFERENTIAL EQUATIONS
C     FOR MODE AMPLITUDES USING THE COEFFICIENTS COMPUTED BY THE
C     PROGRAM TB1. TIME-HISTORY OF A PRESSURE DISTURBANCE IN THE
C     T-BURNER IS COMPUTED AND THE DESIRED PLOTS AND PRINTOUTS
C     ARE PRODUCED.
C
C
C     THE FOLLOWING INPUTS ARE REQUIRED:
C     (1)   THE CONTROL NUMBERS, NOUTCF AND NHISTR.
C     (2)   THE COEFFICIENTS FROM PROGRAM TB1.
C     (3)   THE DATA DECK.
C
C     THE FIRST CARD GIVES THE CONTROL NUMBERS, NOUTCF AND NHISTR.
C          NOUTCF DETERMINES PRINTOUT OF COEFFICIENTS:
C            IF NOUTCF = 0  COEFFICIENTS ARE NOT PRINTED OUT.
C            IF NOUTCF = 1  ONLY LINEAR COEFFICIENTS ARE PRINTED OUT.
C            IF NOUTCF = 2  ALL COEFFICIENTS ARE PRINTED OUT.
C          NHISTR DETERMINES IF PRESSURE HISTORY IS TO BE PRINTED:
C            IF NHISTR = 0  PRINTED
C            IF NHISTR = 1  NOT PRINTED.
C
C     THE COEFFICIENTS ARE OBTAINED FROM PROGRAM TB1
C     BY PUTTING NOUT = 1 OR NOUT = 2, THEREBY WRITING THE COEFFICIENTS
C     INTO A DISK. THIS DISK HAS BEEN GIVEN THE DEVICE NUMBER 9.
C
C     THE DATA DECK CONSISTS OF THE FOLLOWING CARDS:
C
C     FIRST CARD: TITLE OF THE CASE.
C
C     SECOND CARD: H, TSTART, TQUIT, FREQ, BCOMB
C          H IS THE INTEGRATION STEP SIZE.
C          TSTART IS THE TIME AT WHICH OUTPUT STARTS.
C          TQUIT IS THE TIME AT WHICH COMPUTATIONS ARE TERMINATED.
C          FREQ IS THE MOTOR FREQUENCY (IN PURE GAS), IN HERTZ.
C          BCOMB IS THE COMBUSTION RESPONSE NONLINEARITY FACTOR.
C
C     THIRD CARD: A2PARA, B2PARA, EN, OMEGA
C          A2PARA AND B2PARA ARE THE COMBUSTION PARAMETERS
C             IN THE A-B MODEL.
C          EN IS THE PRESSURE EXPONENT IN THE BURNING RATE LAW.
C          OMEGA IS THE FREQUENCY NONDIMENSIONALIZED BY THE SQUARE OF
C          THE STEADY-STATE BURNING RATE.
C
```

```
C        FOURTH CARD: NLOC, NTERMS, NOUT, NCOMB
C           NLOC DETERMINES THE LOCATION OF THE WALL PRESSURE MAXIMA
C           AND MINIMA:
C              IF NLOC = 1     LOCATION IS Z = 0.0
C              IF NLOC = 2     LOCATION IS Z = 1.0
C              IF NLOC = 3     LOCATION IS Z = 0.5
C           NTERMS IS THE NUMBER OF TERMS GIVEN INITIAL VALUES.
C           NOUT IS THE OUTPUT CONTROL NUMBER.
C              IF NOUT = 0     PRINTED OUTPUT ONLY.
C              IF NOUT > 0     BOTH PRINTED AND PLOTTED OUTPUT;
C              IF NOUT = 1     PLOT OF PRESSURE AT Z = 0.0 ONLY.
C              IF NOUT = 2     PLOT OF PRESSURE AT Z = 0.0 AND Z = 1.0
C              IF NOUT = 3     PLOT OF PRESSURE AT Z = 0.0, 1.0 AND 0.5.
C           NCOMB DETERMINES IF COMBUSTION NONLINEARITIES ARE CONSIDERED:
C              IF NCOMB = 0      NEGLECTED.
C              IF NCOMB = 1      INCLUDED.
C
C        NEXT CARD (NECESSARY ONLY IF PLOTS ARE REQUIRED): YHI, YLAB, ITICY
C           YHI IS THE MAXIMUM ORDINATE FOR PRESSURE PLOTS.
C           NOTE: THE ORDINATE SCALES FOR PRESSURE AND AMPLITUDE PLOTS
C                 ARE SYMMETRIC ABOUT ZERO.
C           YLAB IS THE INTERVAL FOR ORDINATE LABELING FOR ABOVE PLOTS.
C           ITICY IS THE NUMBER OF ORDINATE TIC MARKS FOR ABOVE PLOTS.
C           NOTE: ITICY SHOULD BE NEGATIVE FOR PRESSURE AND AMPLITUDE
C                 PLOTS TO OBTAIN CENTERLINE.
C
C        NEXT CARD (NECESSARY ONLY IF PLOTS ARE REQUIRED): MDPLOT
C           MDPLOT DETERMINES IF PLOTS OF INDIVIDUAL MODES ARE REQUIRED:
C              IF PLOT OF J TH MODE IS REQUIRED, PUNCH "1" IN THE
C              5*J TH COLUMN.
C              IF PLOT OF J TH MODE IS NOT REQUIRED, PUNCH "0" IN THE
C              5*J TH COLUMN.
C
C        NEXT CARD (NECESSARY ONLY IF PLOT OF ANY MODE AMPLITUDE IS
C        REQUIRED): YHIMD, YLABMD, ITICMD
C           YHIMD IS THE MAXIMUM ORDINATE.
C           YLABMD IS THE INTERVAL FOR ORDINATE LABELLING.
C           ITICMD IS THE NUMBER OF ORDINATE TIC MARKS FOR MODE PLOTS.
C           NOTE: ITICMD SHOULD BE NEGATIVE TO OBTAIN CENTERLINE.
C
C        REMAINING CARDS (NTERMS IN NUMBER): J, AST, ACT
C           AST IS THE AMPLITUDE OF THE SINE TERM OF THE J TH MODE.
C           ACT IS THE AMPLITUDE OF THE COSINE TERM OF THE J TH MODE.
C
C
C        ****************************************************************
C
C
         COMPLEX     RES(6), CRES
```

```
      DIMENSION    L(6), NAME(6), AA(4), FRQ1(24), CPV(12),
     1             YN(2), YNP(2), FZN(4,2), UN(5,2),  UZN(2),
     2             CFT(3,12), CFZ(3,12), AS(24),
     3             AC(24), U(5,36), Y(36),PRESS(3),
     4             YP(36), FZ(4,36), UZ(36),Z(3), TIMAX(500),
     5             TPLOT(500), YPLOT(3,500), DUMMYT(500), DUMMYY(500),
     6             IBUF(512), ITT(3), ITY1(3),ITY2(3),ITY3(4),
     7             TITLE(7), PRS(500), TI(500), PMAX(500),
     8             MDPLOT(6), UPLOT(6,500), MTITL1(2), MTITL2(2),
     9             MTITL3(2), MTITL4(2), MTITL5(2), MTITL6(2), MTITL(2)
C
      COMMON       C(2,12,24), D(12,144),
     1             CV1(12), CV2(12), CV3(12), CV4(12),
     2             KPMAX(3,12), IC(2,12,24), KPQMAX(12), IDP(12,144),
     3             IDQ(12,144), CPAR(12,24), UNBAR, EL, CP(4,12,24)
      COMMON       /BLK2/      B(6)
      COMMON       /BLK3/      NJMAX, NLMAX, GAMMA, COEF(2,12), NJMAX2
      COMMON       /BLK5/      RES, NCOMB, BCOMB
      COMMON       /BLK7/      BETA, BETAV, RRL, UB, PARTKL, CM,
     1                         NPRTKL, NBURN
C
      DATA    ITT/"DIMENSIONL","ESS TIME, ","T         "/,
     1        ITY1/"HEAD END P","RESSURE PE","RTURBATION"/,
     2        ITY2/"NOZZLE PRE","SSURE PERT","URBATION  "/,
     3        ITY3/"PRESSURE P","ERTURBATIO","N AT THE C","ENTER     "/,
     4        MTITL1/"AMPLITUDE ","OF 1L MODE"/,
     5        MTITL2/"AMPLITUDE ","OF 2L MODE"/,
     6        MTITL3/"AMPLITUDE ","OF 3L MODE"/,
     7        MTITL4/"AMPLITUDE ","OF 4L MODE"/,
     8        MTITL5/"AMPLITUDE ","OF 5L MODE"/,
     9        MTITL6/"AMPLITUDE ","OF 6L MODE"/
C
      MAXMD = 6
      MAXMD2 = 12
      MAXMD4 = 24
      MAXMD6 = 36
      MAXMDD = 144
      LAST = 5
      ERR = 0.001
      TDEL = 10.0
      NPT = 0
      AA(1) = 0.0
      AA(2) = 0.5
      AA(3) = 0.5
      AA(4) = 1.0
      PI = 3.1415926536
      HC = 1.0
      ZE = 1.0
      READ (5,5003) NOUTCF, NHISTR
C
```

```
C     ************* COEFFICIENT INPUT SECTION ***************************
C
C     THIS VERSION OF TB2 READS THE COEFFICIENT DATA FROM
C     A FILE GENERATED BY PROGRAM TB1.   TO READ
C     THIS DATA FROM CARDS, USE READ (5,XXXX) INSTEAD OF
C     READ (9,XXXX) IN THIS SECTION.
C
C     INPUT OF MOTOR PARAMETERS AND NUMBER OF TERMS.
      READ (9,5001) GAMMA, BETA, BETAV, RRL, UB, VL, EL,
     1              NJMAX, NPRTKL, NBURN
      JMX = NJMAX/2
      NJMAX2 = NJMAX
      NU = 2 * NJMAX
      GAM = GAMMA
      FRATIO = 1.0
      AV = PI * BETAV * BETAV / 4.0
      UNBAR = 2.0 * UB * AV * (NBURN + BETA/RRL)
      IF (NPRTKL .EQ. 0) GO TO 14
      READ (9,5011) DIA, RHOM, SP, TEMP, FREQ, PARTKL, CM
      GAM = GAMMA / (1.0 + SP*CM - SP*CM*GAMMA)
      FRATIO = SQRT(GAMMA / (GAM * (1.0 + CM)))
      NJMAX2 = 2*NJMAX
      NU = NJMAX2 + NJMAX
   14 CONTINUE
C
      IF (NBURN .EQ. 0) WRITE (6,6025)
      IF (NBURN .EQ. 1) WRITE (6,6026)
      WRITE (6,6001) BETA, BETAV, RRL, UB, VL, EL, JMX, GAM
      IF (NPRTKL .EQ. 0) WRITE (6,6033)
      IF (NPRTKL .EQ. 1) WRITE (6,6009) GAMMA
      IF (NPRTKL .EQ. 1) WRITE (6,6030) DIA, CM, FREQ,
     1    TEMP, SP, RHOM, PARTKL
      WRITE (6,6002)
C
C     INPUT OF DESCRIPTION OF SERIES EXPANSION.
      DO 10 K = 1, JMX
      READ (9,5002) NJ, L(NJ), NAME(NJ)
      WRITE (6,6003)  NAME(NJ), NJ, L(NJ)
   10 CONTINUE
C
      WRITE (6,6010)
      DO 15 K = 1, JMX
      READ (9,5010) J, B(J)
      WRITE (6,6015) J, B(J)
   15 CONTINUE
C
C     ZERO LINEAR COEFFICIENT ARRAYS.
      DO 20 KC = 1, 4
      DO 20 NJ = 1, MAXMD2
      DO 20 NP = 1, MAXMD4
      CP(KC,NJ,NP) = 0.0
   20 CONTINUE
```

```
C
C     ZERO NONLINEAR COEFFICIENT ARRAY.
      DO 30 NJ = 1, MAXMD2
      DO 30 NPQ = 1, MAXMDD
      D(NJ,NPQ) = 0.0
   30 CONTINUE
C
C     INPUT OF LINEAR COEFFICIENTS.
      DO 40 KC = 1, 4
      READ (9,5003) KMAX
      IF (NOUTCF .GT. 0) WRITE (6,6004) KC, KMAX
      IF (KMAX .EQ. 0)  GO TO 40
      DO 45 K = 1, KMAX
      READ (9,5004) NJ, NP, CP(KC,NJ,NP)
      IF (NOUTCF .GT. 0) WRITE (6,6005) KC, NJ, NP, CP(KC,NJ,NP)
   45 CONTINUE
   40 CONTINUE
C
      DO 305 K = 1, NJMAX
      READ (9,5016) J, CPV(J)
  305 CONTINUE
C
      READ (9,5003) KMAXPR
      IF (NOUTCF .GT. 0) WRITE (6,6036) KMAXPR
      IF (KMAXPR .EQ. 0) GO TO 1040
      DO 1042 K = 1, KMAXPR
      READ (9,5004) NJ, NP, CPAR(NJ,NP)
      IF (NOUTCF .GT. 0) WRITE (6,6037) NJ, NP, CPAR(NJ,NP)
 1042 CONTINUE
 1040 CONTINUE
C
C     INPUT OF NONLINEAR COEFFICIENTS.
      READ (9,5003) NLMAX
      IF (NOUTCF .EQ. 2)  WRITE (6,6006) NLMAX
      IF (NLMAX .EQ. 0)  GO TO 50
      DO 52 NJ = 1, MAXMD2
      KPQMAX(NJ) = 0
   52 CONTINUE
      DO 55 K = 1, NLMAX
      READ (9,5005)  NJ, NP, NQ, DT
      IF (NOUTCF .EQ. 2)  WRITE (6,6007)  NJ, NP, NQ, DT
      KPQMAX(NJ) = KPQMAX(NJ) + 1
      KPQ = KPQMAX(NJ)
      IDP(NJ,KPQ) = NP
      IDQ(NJ,KPQ) = NQ
      D(NJ,KPQ) = DT
   55 CONTINUE
   50 CONTINUE
C
```

```
C       ************* PRESSURE COEFFICIENT SECTION ***********************
C
C       CALCULATE SPATIAL COORDINATES FOR PRESSURE COMPUTATION.
        Z(1) = 0.0
        Z(2) = ZE
        Z(3) = 0.5 * ZE
C
C       CALCULATE COEFFICIENTS FOR PRESSURE TIME HISTORIES.
        DO 53 NPRES = 1, 3
        DO 53 J = 1, JMX
        NP = (2 * J) - 1
        AXLOC = Z(NPRES)
        CALL PHICFS(J,AXLOC,C1,C3)
        CFT(NPRES,NP) = C1
        CFZ(NPRES,NP) = C3
        CFT(NPRES,NP+1) = CFZ(NPRES,NP+1) = 0.0
     53 CONTINUE
C
C       OUTPUT OF COEFFICIENTS FOR PRESSURE TIME HISTORIES.
        WRITE (6,6020)
        DO 56 NPRES = 1, 3
        WRITE (6,6014)
        DO 56 J = 1, NJMAX
        WRITE (6,6021) J, Z(NPRES), CFT(NPRES,J), CFZ(NPRES,J)
     56 CONTINUE
C
C       ************* DATA INPUT SECTION *********************************
C
        READ (5,5000) TITLE
C
C       ZERO INITIAL VALUE AND FREQUENCY ARRAYS.
      5 DO 57 K = 1, NJMAX2
        AS(K) = 0.0
        AC(K) = 0.0
        FRQ1(K) = 0.0
     57 CONTINUE
C
C
C       READ COMBUSTION AND CONTROL PARAMETERS.
        READ (5,5006) H, TSTART, TQUIT, FREQ, BCOMB
        IF (EOF(5)) 300, 1
      1 CONTINUE
        READ (5,5013) A2PARA, B2PARA, EN, OMEGA
        WRITE (6,6034) A2PARA, B2PARA, EN, OMEGA
        DO 46 K = 1, JMX
        OMEGAK = OMEGA * K
        CALL RESPNS(EN,A2PARA,B2PARA,OMEGAK,CRES)
        RES(K) = CRES
        WRITE (6,6035) K, RES(K)
     46 CONTINUE
C
```

```
C     READ CONTROL NUMBERS.
      READ (5,5008)  NLOC, NTERMS, NOUT, NCOMB
      IF (NOUT .GT. 0)  NPT = 1
      IF (NCOMB .EQ. 0) WRITE (6,6039)
      IF (NCOMB .EQ. 1) WRITE (6,6040) BCOMB
      WRITE (6,6041)
C
C
      IF (NOUT .EQ. 0)  GO TO 9
C     READ DATA FOR SETTING UP PLOTS.
      READ (5,5009) YHI, YLAB, ITICY
      READ (5,5014) MDPLOT
      MDPLTL = 0
      DO 320 K = 1, JMX
  320 MDPLTL = MDPLTL + MDPLOT(K)
      IF (MDPLTL .EQ. 0) GO TO 9
      READ (5,5015) YHIMD, YLABMD, ITICMD
      YLOMD = - YHIMD
C
C     ************ INITIAL AMPLITUDES SECTION ***************************
C
    9 DO 54 K = 1, NTERMS
C
C     INPUT INITIAL AMPLITUDES FOR F-FUNCTIONS.
      READ (5,5007)  J, AST, ACT
      NJ = (2 * J) - 1
      AS(NJ) = AST
      AC(NJ) = ACT
C
C     CALCULATE FREQUENCY.
      AX = L(J) * PI * FRATIO/ZE
      FRQ1(NJ) = AX
      FRQ1(NJ+1) = FRQ1(NJ)
  583 AC(NJ+1) = -AS(NJ)
      AS(NJ+1) = AC(NJ)
C
   58 CONTINUE
      IF (NPRTKL .EQ. 0) GO TO 54
      AS(NJ+NJMAX) = AS(NJ)
      AC(NJ+NJMAX) = AC(NJ)
      AS(NJ+1+NJMAX) = AS(NJ+1)
      AC(NJ+1+NJMAX) = AC(NJ+1)
   54 CONTINUE
C
C
C     OUTPUT OF INITIAL AMPLITUDES.
      WRITE (6,6016)
      DO 590 J = 1, NJMAX
      IF (AS(J))  591, 592, 591
  592 IF (AC(J))  591, 590, 591
  591 WRITE (6,6017) J, FRQ1(J), AC(J), AS(J)
  590 CONTINUE
      IF (NOUT .GE. 1)  WRITE (6,6027)
```

```
C
C     ************* LINEAR COEFFICIENTS SECTION *************************
C
      DO 59 KC = 1, 3
      DO 59 NJ = 1, MAXMD2
      KPMAX(KC,NJ) = 0
   59 CONTINUE
C
      DO 315 KC = 1, 2
      DO 315 NJ = 1, MAXMD2
      DO 315 NP = 1, MAXMD4
      C(KC,NJ,NP) = 0.0
  315 CONTINUE
C
C     COMPUTE LINEAR COEFFICIENTS FOR GIVEN VALUES OF
C     HC AND RESPONSE FUNCTION.
  605 DO 60 NJ = 1, NJMAX
      CV1(NJ) = CV2(NJ) = 0.0
      IF (NJ .NE. (NJ/2)*2) CV1(NJ) = CPV(NJ) * HC
      IF (NJ .EQ. (NJ/2)*2) CV2(NJ) = CPV(NJ) * HC
      CV3(NJ) = (GAMMA*BETAV) / (EL*AV*HC) * CV1(NJ)
      CV4(NJ) = (GAMMA*BETAV) / (EL*AV*HC) * CV2(NJ)
      DO 60 NP = 1, NJMAX2
      CT = CP(1,NJ,NP)
      IF (CT) 61, 62, 61
   61 KPMAX(1,NJ) = KPMAX(1,NJ) + 1
      KP = KPMAX(1,NJ)
      IC(1,NJ,KP) = NP
      C(1,NJ,KP) = CT
   62 CONTINUE
      IF (NP .GT. NJMAX .OR. NJ .GT. NJMAX) GO TO 316
      NP12 = (NP+1)/2
      RESR = REAL (RES(NP12))
      RESI = AIMAG (RES(NP12))
      CT = CP(2,NJ,NP) + HC*RESR*CP(3,NJ,NP) + HC*RESI*CP(4,NJ,NP)
      GO TO 318
  316 CONTINUE
      CT = CP(2,NJ,NP)
  318 CONTINUE
      IF(CT) 63, 60, 63
   63 KPMAX(2,NJ) = KPMAX(2,NJ) + 1
      KP = KPMAX(2,NJ)
      IC(2,NJ,KP) = NP
      C(2,NJ,KP) = CT
   60 CONTINUE
C
C     ************* INITIAL VALUES SECTION ******************************
C
      NSTEP = 0
      NP1 = 3
      H6 = H/6
      TIME = 0.0
      I = NP1
      TI(I) = TIME
```

```
C
      DO 75 J = 1, NJMAX2
      JP = J + NJMAX2
      IF (AC(J)) 751, 753, 751
  753 IF (AS(J)) 751, 752, 751
  752 U(I,J) = 0.0
      IF (JP .GT. NU) GO TO 75
      U(I,JP) = 0.0
      GO TO 75
  751 ARG = FRQ1(J) * TIME
      FSIN = SIN(ARG)
      FCOS = COS(ARG)
      U(I,J) = AS(J)*FSIN + AC(J)*FCOS
      IF (JP .GT. NU) GO TO 75
      U(I,JP) = ((AS(J) * FCOS) - (AC(J) * FSIN)) * FRQ1(J)
   75 CONTINUE
C     CALCULATE INITIAL VALUES OF PRESSURE AND VELOCITY.
      DO 704 NPRES = 1, 3
      DO 702 J = 1, NJMAX
      COEF(1,J) = CFT(NPRES,J)
      COEF(2,J) = CFZ(NPRES,J)
  702 CONTINUE
      DO 703 J = 1, NU
      Y(J) = U(I,J)
  703 CONTINUE
      AXLOC = Z(NPRES)
      CALL PRSVEL(AXLOC,VL,Y,P,VZGAS,VZPAR)
      PRESS(NPRES) = P
  704 CONTINUE
      PRS(I) = PRESS(NLOC)
   70 CONTINUE
C
      IF (NHISTR .EQ. 0) WRITE (6,6022)
C
C     ************* INITIALIZE CONTROL NUMBERS **************************
C
      LINE = 8
      K = 0
      MAXNO = 0
      MAXP = 0
      IF (NOUT .EQ. 0)  GO TO 100
      JPLOT = 0
      TMIN = TSTART
      TMAX = TSTART + TDEL
      YLO = -YHI
C
C     ************* NUMERICAL CALCULATIONS SECTION ********************
C
  100 I = NP1
C
```

```
C     RUNGE-KUTTA INTEGRATION SCHEME.
  105 NSTEP = I - NP1 + (LAST - NP1) * K
      RSTEP = NSTEP
      TIME = RSTEP * H
      TI(I) = TIME
      DO 120 J = 1, NU
      Y(J) = U(I,J)
  120 CONTINUE
      YN(1) = UN(I,1)
      YN(2) = UN(I,2)
      CALL RHS(Y,YP,YN,YNP)
      DO 130 J = 1, NU
      FZ(1,J) = YP(J)
  130 CONTINUE
      FZN(1,1) = YNP(1)
      FZN(1,2) = YNP(2)
      DO 140 II = 2,4
      DO 144 J = 1, NU
      UZ(J) = Y(J) + AA(II) * H * FZ(II-1,J)
  144 CONTINUE
      UZN(1) = YN(1) + AA(II) * H * FZN(II-1,1)
      UZN(2) = YN(2) + AA(II) * H * FZN(II-1,2)
      CALL RHS(UZ,YP,UZN,YNP)
      DO 148 J = 1, NU
      FZ(II,J) = YP(J)
  148 CONTINUE
      FZN(II,1) = YNP(1)
      FZN(II,2) = YNP(2)
  140 CONTINUE
      DO 150 J = 1, NU
      U(I+1,J) = Y(J) + (FZ(1,J)+2.0*(FZ(2,J)+FZ(3,J)) + FZ(4,J)) * H6
  150 CONTINUE
      UN(I+1,1) = YN(1) + (FZN(1,1) + 2.0 * (FZN(2,1)+FZN(3,1))
     1            + FZN(4,1)) * H6
      UN(I+1,2) = YN(2) + (FZN(1,2) + 2.0 * (FZN(2,2)+FZN(3,2))
     1            + FZN(4,2)) * H6
C
C     CALCULATE PRESSURE TIME HISTORIES.
      DO 154 NPRES = 1, 3
      DO 152 J = 1, NJMAX
      COEF(1,J) = CFT(NPRES,J)
      COEF(2,J) = CFZ(NPRES,J)
  152 CONTINUE
      AXLOC = Z(NPRES)
      CALL PRSVEL(AXLOC,VL,Y,P,VZGAS,VZPAR)
      PRESS(NPRES) = P
  154 CONTINUE
      PRS(I) = PRESS(NLOC)
      IF (K .EQ. 0) GO TO 175
C
```

```
C     DETERMINE MAXIMUM AND MINIMUM PRESSURE AT LOCATION SPECIFIED
C     BY NLOC.
      DPL = PRS(I) - PRS(I-1)
      DPS = PRS(I-1) - PRS(I-2)
      IF (DPL*DPS) 173, 173, 175
  173 PNUM = PRS(I-2) - PRS(I)
      PDEN = 2.0 * (PRS(I-2) + PRS(I) - 2.0*PRS(I-1))
      IF (PDEN) 174, 175, 174
  174 PP = PNUM/PDEN
      PA = (PP - 1.0) * PP * 0.5
      PB = 1.0 - (PP * PP)
      PC = (PP + 1.0) * PP * 0.5
      MAXP = MAXP + 1
      PMAX(MAXP) = PA*PRS(I-2) + PB*PRS(I-1) + PC*PRS(I)
      TIMAX(MAXP) = TI(I-1) + PP*H
      IF (MAXP .GE. 500)  GO TO 250
  175 CONTINUE
C
      IF (TIME .LT. TSTART)  GO TO 155
      IF ((NOUT .EQ. 0) .OR. (NOUT .GT. 6))  GO TO 156
C
C     ************* TIME HISTORY PLOTTING SECTION ********************
C
      IF (TMAX .GT. TQUIT)  GO TO 156
      IF ((TIME .GT. TMAX) .OR. (JPLOT .GE. 500))  GO TO 1000
C
      JPLOT = JPLOT + 1
C
C     FILL TIME ARRAY FOR PLOTTING.
      TPLOT(JPLOT) = TIME
C
C     FILL PRESSURE ARRAYS FOR PLOTTING.
      DO 1001 J = 1,3
      YPLOT(J,JPLOT) = PRESS(J)
 1001 CONTINUE
C
C
      IF (MDPLTL .EQ. 0) GO TO 156
C     FILL MODE AMPLITUDE ARRAYS FOR PLOTTING.
      DO 322 J = 1, JMX
      IF (MDPLOT(J) .EQ. 0) GO TO 322
      J12 = 2*J - 1
      UPLOT(J,JPLOT) = U(I,J12)
  322 CONTINUE
C
      GO TO 156
C
 1000 NUM = JPLOT
C
```

```
C     PLOT TIME HISTORIES.
C
      DO 1020 NPLOT = 1, NOUT
C
      JPLOT = 0
C
C     ASSIGN PLOTTING PARAMETERS.
      YMIN = YLO
      YMAX = YHI
      NTICY = ITICY
      DELY = YLAB
C
C     ELIMINATE POINTS THAT ARE OUT OF THE ORDINATE RANGE.
      DO 1010 J = 1, NUM
      IF ((YPLOT(NPLOT,J) .LT. YMIN) .OR. (YPLOT(NPLOT,J) .GT. YMAX))
     1   GO TO 1010
      JPLOT = JPLOT + 1
      DUMMYT(JPLOT) = TPLOT(J)
      DUMMYY(JPLOT) = YPLOT(NPLOT,J)
 1010 CONTINUE
C
      IF (JPLOT .EQ. 0)  GO TO 1020
      GO TO (1011,1014,1015), NPLOT
C
C     PLOT HEAD-END PRESSURE.
 1011 CALL GRAPHS(IBUF,512,4,JPLOT,11,NTICY,TMAX,YMAX,TMIN,YMIN,
     1            ITT,ITY1,21,30,DUMMYT,DUMMYY,2.0,DELY,TITLE)
      GO TO 1020
C
C     PLOT NOZZLE PRESSURE.
 1014 CALL GRAPHS(IBUF,512,4,JPLOT,11,NTICY,TMAX,YMAX,TMIN,YMIN,
     1            ITT,ITY2,21,28,DUMMYT,DUMMYY,2.0,DELY,TITLE)
      GO TO 1020
C
C     PLOT PRESSURE AT THE CENTER (X = 0.5).
 1015 CALL GRAPHS(IBUF,512,4,JPLOT,11,NTICY,TMAX,YMAX,TMIN,YMIN,
     1            ITT,ITY3,21,35,DUMMYT,DUMMYY,2.0,DELY,TITLE)
C
 1020 CONTINUE
C
      DO 324 NPLOT = 1, JMX
      IF (MDPLOT(NPLOT) .EQ. 0) GO TO 324
      JPLOT = 0
      DO 328 J123 = 1, 2
      IF (NPLOT .EQ. 1) MTITL(J123) = MTITL1(J123)
      IF (NPLOT .EQ. 2) MTITL(J123) = MTITL2(J123)
      IF (NPLOT .EQ. 3) MTITL(J123) = MTITL3(J123)
      IF (NPLOT .EQ. 4) MTITL(J123) = MTITL4(J123)
      IF (NPLOT .EQ. 5) MTITL(J123) = MTITL5(J123)
      IF (NPLOT .EQ. 6) MTITL(J123) = MTITL6(J123)
  328 CONTINUE
```

```
      DO 326 J = 1, NUM
      IF ((UPLOT(NPLOT,J) .LT. YLOMD) .OR. (UPLOT(NPLOT,J)
     1     .GT. YHIMD)) GO TO 326
      JPLOT = JPLOT + 1
      DUMMYT(JPLOT) = TPLOT(J)
      DUMMYY(JPLOT) = UPLOT(NPLOT,J)
  326 CONTINUE
      IF (JPLOT .EQ. 0) GO TO 324
      CALL GRAPHS(IBUF,512,4,JPLOT,11,ITICMD,TMAX,YHIMD,TMIN,
     1     YLOMD,ITT,MTITL,21,20,DUMMYT,DUMMYY,2.0,YLABMD,TITLE)
  324 CONTINUE
C
C     REASSIGN PLOTTING PARAMETERS FOR NEXT SET OF PLOTS.
      JPLOT = 0
      TMIN = TMAX
      TMAX = TMAX + TDEL
C
C     ************* TIME HISTORY PRINTED OUTPUT SECTION ****************
C
  156 IF (NHISTR .EQ. 0)
     1     WRITE (6,6011) NSTEP, TIME, (PRESS(J), J = 1,3), VZGAS, VZPAR
      LINE = LINE + 1
  157 IF (TIME .GT. TQUIT)  GO TO 250
      IF (LINE .LT. 52)  GO TO 155
      IF (NHISTR .EQ. 0) WRITE (6,6013)
      IF (NHISTR .EQ. 0) WRITE (6,6022)
      LINE = 4
C
  155 I = I + 1
      IF (I .LT. LAST)  GO TO 105
      K = K + 1
C
C     RE-ASSIGN ARRAYS.
  190 DO 200 I = 1, NP1
      ILAST = LAST - NP1 + I
      PRS(I) = PRS(ILAST)
      TI(I) = TI(ILAST)
      DO 200 J = 1, NU
      U(I,J) = U(ILAST,J)
  200 CONTINUE
      GO TO 100
C
C
C     ************* PRESSURE MAXIMA AND MINIMA PRINTOUT ***************
C
  250 WRITE (6,6023) Z(NLOC), MAXP
      LINE = 4
      DO 255 JST = 1, MAXP, 8
      JSTART = JST
      JSTOP = JST + 7
      IF (JSTOP .GT. MAXP) JSTOP = MAXP
      WRITE (6,6024) (PMAX(J), J = JSTART, JSTOP)
      WRITE (6,6024) (TIMAX(J), J = JSTART, JSTOP)
```

```
      WRITE (6,6014)
      LINE = LINE + 3
      IF (LINE .LT. 52)  GO TO 255
      LINE = 0
      WRITE (6,6013)
  255 CONTINUE
      CALL GROWTH(MAXP,TIMAX,PMAX,FREQ)
C
      GO TO 5
  300 CONTINUE
C
C     TURN OFF PLOTTING ROUTINE.
      IF (NPT .EQ. 1)  CALL PLOT(0.0,0.0,999)
C
C     ************** READ FORMAT SPECIFICATIONS *************************
C
 5000 FORMAT (7A10)
 5001 FORMAT (7F10.0,3I5)
 5002 FORMAT (2I5,1X,A4)
 5003 FORMAT (2I5)
 5004 FORMAT (2I5,F15.8)
 5005 FORMAT (3I5,F15.8)
 5006 FORMAT (7F10.0)
 5007 FORMAT (I5,2F10.0)
 5008 FORMAT (6I5)
 5009 FORMAT (2F10.0,I5)
 5010 FORMAT (I5,2F12.8)
 5011 FORMAT (7F15.8)
 5012 FORMAT (I5,2F10.0)
 5013 FORMAT (4F10.0)
 5014 FORMAT (6I5)
 5015 FORMAT (2F10.0,I5)
 5016 FORMAT (I5,F12.8)
C
C     ************** WRITE FORMAT SPECIFICATIONS ************************
C
 6001 FORMAT (6X,6HBETA =,F7.5,//,6X,7HBETAV =,F7.5,//,
     1        6X,5HR/L =,F7.5,//,6X,4HUB =,F7.5,//,6X,4HVL =,
     2        F4.1,//,6X,4HEL =,F8.5,//,6X,17HNUMBER OF MODES =,
     3        I2,//,6X,7HGAMMA =,F5.2)
 6002 FORMAT (6X,14HNAME     J     L/)
 6003 FORMAT (6X,A4,2I5)
 6004 FORMAT (1H0,26H NUMBER OF COEFFICIENTS C(,I1,10H,NJ,NP) IS,I5/)
 6005 FORMAT (2X,2HC(,I1,1H,,I2,1H,,I2,4H) = ,F10.5)
 6006 FORMAT (1H0,38H NUMBER OF COEFFICIENTS D(NJ,NP,NQ) IS,I5/)
 6007 FORMAT (2X,2HD(,I2,1H,,I2,1H,,I2,4H) = ,F10.5)
 6009 FORMAT (/,6X,10HGAMMABAR =,F9.6,//)
 6010 FORMAT (1H0,////,6X,1HJ,10X,4HB(J)//)
 6011 FORMAT (2X,I5,F12.5,5F22.5)
 6012 FORMAT (1H0)
```

```
6013 FORMAT (1H1)
6014 FORMAT (1H )
6015 FORMAT (2X,I5,4X,F10.5)
6016 FORMAT (1H1,36H INITIAL CONDITIONS ARE OF THE FORM://
    1        2X,47HU(I,J) =   AC(J)*COS(FREQ*T) + AS(J)*SIN(FREQ*T),
    2        ////6X,1HJ,6X,9HFREQUENCY,10X,5HAC(J),10X,5HAS(J)//)
6017 FORMAT (2X,I5,4F15.8/)
6020 FORMAT (1H1,46H COEFFICIENTS FOR COMPUTATION OF WALL PRESSURE,
    1        10H WAVEFORMS///43X,27HCOEFFICIENTS IN SERIES FOR://
    2        37X,4HTIME,21X,5HAXIAL/6X,1HJ,9X,1HZ,17X,10HDERIVATIVE,
    3        15X,10HDERIVATIVE//)
6021 FORMAT (2X,I5,F10.3,12X,F15.7,10X,F15.7)
6022 FORMAT (3X,4HSTEP,8X,4HTIME,15X,8HPRESSURE,14X,8HPRESSURE,14X,
    1        8HPRESSURE,14X,7HGAS VEL,15X,7HPAR VEL,/,34X,
    2        8HAT Z=0.0,14X,8HAT Z=1.0,14X,8HAT Z=0.5,13X,
    3        8HAT Z=0.5,14X,8HAT Z=0.5//)
6023 FORMAT (1H1,38H PRESSURE MAXIMA AND MINIMA AT:    Z = ,F5.2,
    1        /19H VALUES COMPUTED:   ,I3//)
6024 FORMAT (1H ,7X,8F13.6)
6025 FORMAT (1H1,//,6X,15HNO END BURNING.,/)
6026 FORMAT (1H1,//,6X,23HEND BURNING IS PRESENT.,/)
6027 FORMAT (2X//2X,33HTHIS RUN PRODUCES PLOTTED OUTPUT.)
6030 FORMAT (///,6X,27HPARTICLE DIA (IN MICRONS) = ,F5.2,10X,
    1        4HCM =,F4.2,10X,18HFREQ (IN HERTZ) = ,F6.1,//,
    2        6X,26HCHAMBER TEMP (IN DEG K) = ,F6.1,10X,4HSP =,
    3        F4.2,10X,27HRHOM (IN KG/CUBIC METER) = ,F6.1,//,6X,
    4        27HPARTICLE DRAG CONSTANT, K =,F8.4,////)
6032 FORMAT (2X,2HE(,I2,1H,,I2,1H,,I1,4H) = ,F10.5)
6033 FORMAT (/////,6X,26HPARTICLES ARE NOT PRESENT.//)
6034 FORMAT (1H1,///,3X,22HCOMBUSTION PARAMETERS:,5X,3HA =,F7.4,6X,
    1        3HB =,F6.4,5X,4HEN =,F5.3,5X,7HOMEGA =,F6.3,
    2        //////,25X,1HJ,16X,4HRESR,15X,4HRESI,//)
6035 FORMAT (1H0,20X,I5,10X,F10.4,9X,F10.4)
6036 FORMAT (1H0,47HNUMBER OF COEFFICIENTS IN PARTICLE EQUATIONS IS,
    1        I5/)
6037 FORMAT (2X,5HCPAR(,I2,1H,,I2,4H) = ,F10.5)
6039 FORMAT (///,3X,27HLINEAR COMBUSTION RESPONSE.)
6040 FORMAT (///,3X,30HNONLINEAR COMBUSTION RESPONSE:,
    1        5X,8HBCOMB = ,F6.3)
6041 FORMAT (//////,3X,24HLINEAR PARTICLE DAMPING.)
     END
```

```
      SUBROUTINE PHICFS(NP,Z,CT,CZ)
C
C     THIS SUBROUTINE COMPUTES THE COEFFICIENTS NEEDED TO
C     CALCULATE THE PRESSURE PERTURBATION.
C
C     NP IS THE INDEX OF THE COMPLEX SERIES TERM.
C     Z IS THE AXIAL LOCATION.
C     CT IS THE COEFFICIENT IN THE SERIES FOR THE TIME DERIVATIVE OF
C     THE VELOCITY POTENTIAL.
C
C     CZ IS THE COEFFICIENT IN THE SERIES FOR THE AXIAL DERIVATIVE
C     OF THE VELOCITY POTENTIAL.
C
      COMMON     /BLK2/   B(6)
C
      CT = COS(B(NP)*Z)
      CZ = - B(NP) * SIN(B(NP)*Z)
C
      RETURN
      END
```

```
      SUBROUTINE PRSVEL(AXLOC,VL,Y,P,VZGAS,VZPAR)
C
C     THIS SUBROUTINE COMPUTES THE PRESSURE AND VELOCITY.
C
C     AXLOC IS THE AXIAL LOCATION IN THE BURNER WHERE PRESSURE AND
C     VELOCITY ARE TO BE DETERMINED.
C     Y IS THE ARRAY CONTAINING VALUES OF THE MODE-AMPLITUDE
C     FUNCTIONS AND THEIR DERIVATIVES.
C     P IS THE VALUE OF THE PRESSURE PERTURBATION.
C     VZGAS IS THE AXIAL COMPONENT OF GAS VELOCITY.
C     VZPAR IS THE AXIAL COMPONENT OF PARTICLE VELOCITY.
C
C
      DIMENSION     Y(36), SUM(5), SUMSQ(2)
      COMMON        /BLK3/     NJMAX, NLMAX, GAMMA, COEF(2,12), NJMAX2
      COMMON        /BLK7/     BETA, BETAV, RRL, UB, PARTKL, CM,
     1                         NPRTKL, NBURN
C
      BETAV2 = BETAV/2.0
      CALL STEADY(AXLOC,UBAR,UPBAR,RHOP,DUBAR,DUPBAR)
      DO 10 I = 1, 5
      SUM(I) = 0.0
   10 CONTINUE
C
      DO 20 J = 1, NJMAX
      JY = J + NJMAX2
   20 SUM(1) = SUM(1) + Y(JY) * COEF(1,J)
      DO 50 J = 1, NJMAX
      SUM(2) = SUM(2) + Y(J) * COEF(2,J)
      SUM(3) = SUM(3) + Y(J) * COEF(1,J)
      IF (NPRTKL .EQ. 0) GO TO 50
      JP = J + NJMAX
      SUM(4) = SUM(4) + (Y(J)-Y(JP)) * COEF(1,J)
      SUM(5) = SUM(5) + COEF(2,J) * Y(JP)
   50 CONTINUE
      PLIN = SUM(1) + UBAR * SUM(2) + DUBAR * SUM(3)
     1       + PARTKL * RHOP * SUM(4)
      IF (AXLOC .GT. 0.5-BETAV2 .AND. AXLOC .LT. 0.5+BETAV2)
     1    PLIN = PLIN - VL * DUBAR * SUM(3)
      PNL = 0.0
      IF (NLMAX .EQ. 0)  GO TO 40
      DO 30 I = 1, 2
      SUMSQ(I) = SUM(I) * SUM(I)
   30 CONTINUE
      PNL = 0.5 * (SUMSQ(2) - SUMSQ(1))
C
   40 P = -GAMMA * (PLIN + PNL)
      VZGAS = SUM(2)
      VZPAR = SUM(5)
C
      RETURN
      END
```

```
      SUBROUTINE RHS(U,UP,UN,UNP)
C
C
      COMPLEX        RES(6), RESNL(6)
      DIMENSION      U(36), UP(36), UN(2), UNP(2)
      COMMON         C(2,12,24), D(12,144),
     1               CV1(12), CV2(12), CV3(12), CV4(12),
     2               KPMAX(3,12), IC(2,12,24), KPQMAX(12), IDP(12,144),
     3               IDQ(12,144), CPAR(12,24), UNBAR, EL, CP(4,12,24)
      COMMON         /BLK3/     NJMAX, NLMAX, GAMMA, COEF(2,12), NJMAX2
      COMMON         /BLK5/     RES, NCOMB, BCOMB
      COMMON         /BLK7/     BETA, BETAV, RRL, UB, PARTKL, CM,
     1                          NPRTKL, NBURN
C
      IF (NPRTKL .EQ. 0) GO TO 110
      NJS = NJMAX + 1
      DO 112 NJ = NJS, NJMAX2
      NJPAR = NJ - NJMAX
      SLP = 0.0
      DO 114 KP = 1, NJMAX2
      SLP = SLP + (CPAR(NJPAR,KP) * U(KP))
  114 CONTINUE
      UP(NJ) = - SLP
  112 CONTINUE
  110 CONTINUE
      IF (NCOMB .EQ. 0) GO TO 116
      JMX = NJMAX/2
      DO 118 NJ = 1, JMX
      NJPLNJ = 2*NJ
      NJ2MN1 = NJPLNJ - 1
      RESNL(NJ) = RES(NJ) * BCOMB * SQRT (UP(NJ2MN1)**2+UP(NJPLNJ)**2)
  118 CONTINUE
  116 CONTINUE
      DO 10 NJ = 1, NJMAX
      NJP = NJ + NJMAX2
      UP(NJ) = U(NJP)
      SL1 = 0.0
      SL2 = 0.0
      SLV = 0.0
      SNL1 = 0.0
      SNLC = 0.0
      MAX = KPMAX(1,NJ)
      IF (MAX .EQ. 0) GO TO 25
      DO 20 KP = 1, MAX
      NP = IC(1,NJ,KP)
      SL1 = SL1 + (C(1,NJ,KP) * U(NP))
   20 CONTINUE
   25 MAX = KPMAX(2,NJ)
      IF (MAX .EQ. 0) GO TO 45
      DO 30 KP = 1, MAX
      NP = IC(2,NJ,KP)
      SL2 = SL2 + (C(2,NJ,KP) * UP(NP))
   30 CONTINUE
```

AD-A045 118 GEORGIA INST OF TECH ATLANTA SCHOOL OF AEROSPACE ENG--ETC F/G 21/8.2
APPROXIMATE NONLINEAR ANALYSIS OF SOLID ROCKET MOTORS AND T-BUR--ETC(U)
JUL 77 E A POWELL, M S PADMANABHAN, B T ZINN F04611-75-C-0036
UNCLASSIFIED AFRPL-TR-77-48-VOL-2 NL

4 OF 4
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```
45 IF (NLMAX .EQ. 0)  GO TO 55
   MAX = KPQMAX(NJ)
   IF (MAX .EQ. 0) GO TO 55
   DO 50 KPQ = 1, MAX
   NP = IDP(NJ,KPQ)
   NQP = IDQ(NJ,KPQ) + NJMAX2
   SNL1 = SNL1 + (D(NJ,KPQ) * U(NP) * U(NQP))
50 CONTINUE
55 CONTINUE
   SLV = CV1(NJ) * UN(1) + CV2(NJ) * UN(2)
   IF (NCOMB .EQ. 0) GO TO 65
   DO 60 KP = 1, NJMAX
   KP12 = (KP+1)/2
   SNLC = SNLC + (REAL(RESNL(KP12)) * CP(3,NJ,KP) +
  1     AIMAG(RESNL(KP12)) * CP(4,NJ,KP)) * UP(KP)
60 CONTINUE
65 UP(NJP) = -(SL1 + SL2 + SLV + SNL1 + SNLC)
10 CONTINUE
C
   SLU = 0.0
   DO 220 KP = 1, NJMAX
220 SLU = SLU + CV3(KP) * U(KP)
   UNP(1) = - (UNBAR/EL) * UN(1) + SLU
   SLU = 0.0
   DO 230 KP = 1, NJMAX
230 SLU = SLU + CV4(KP) * U(KP)
   UNP(2) = - (UNBAR/EL) * UN(2) + SLU
   RETURN
   END
```

5. "EXACT" PROGRAM FOR MOTORS

Program KZM calculates "exact" instability solutions for solid rocket motors with full-length tubular propellant grains by numerically integrating the conservation equations for a gas-particle mixture (i.e., Equations (85) through (90)). The main purpose of this program is to generate "exact" solutions for comparison with the approximate solutions obtained with SOLID2 or MA2. For this reason, program KZM has the following characteristics: (1) it is restricted to motors with quasi-steady nozzles; (2) a linear combustion option is included in addition to the basic nonlinear pressure-coupled combustion response; and (3) a linear particle drag (Stokes Law) option is included in addition to the nonlinear particle drag law. The theoretical basis for KZM is given in Section 3 of Volume I of this report and in Reference 3.

5.1 Program Description of KZM.

Program KZM consists of a calling program (MAIN) and several subroutines. The main program reads two control parameters and calls subroutines INPUT and START which in turn call other subroutines.

Subroutine INPUT reads the parameters necessary to describe the solid rocket motor under consideration. These include motor length, diameter, and Mach number; chamber pressure and temperature; propellant and gas properties; particle properties; and reference quantities. Subroutine INPUT also prints out the values of the above quantities, sets up the initial thermal profiles in the solid propellant, calculates and prints out the combustion parameters A and B (for linear combustion option only), and returns to MAIN.

Subroutine START reads additional parameters (description of initial disturbance and number of integration time steps performed), calculates the steady-state properties for the motor (uses subroutine CØMBNT), calculates the initial disturbance, prints out the steady-state and initial disturbance profiles (by calling subroutine ØUTPUT), and calls subroutine LØGIC.

Subroutine LØGIC controls the integration of the conservation equations by calculating the time-step-size, calling subroutines BNDMØC and NØZMØC to calculate the boundary values at the head-end and nozzle-end respectively, and calling subroutine TAYLØR to calculate the dependent variables at the interior grid points using a Taylor series expansion (Reference 3). The burning rate at each grid point is calculated using subroutines NUTEMP (which calls THRMWV or LINTHW) and CØMBNT. Subroutine LØGIC also calculates pressure maxima and minima, tests for shock development (using subroutine SHDETL), and produces printed

(subroutine ØUTPUT) and plotted (subroutine GRAPHS) output. After these tasks are completed by LØGIC, control is returned to MAIN (via START) and the job is completed.

5.2 Description of Input.

The inputs are divided into four sections according to the subroutines in which the READ statements appear: MAIN, INPUT, START, and LØGIC. These input sections are described in sequence below, where the format is the same as given previously for the approximate programs (five columns for integers and ten columns for real numbers).

Inputs in MAIN. The MAIN program reads the first card of the data deck which gives the two integer control numbers described below:

NØPT = 0 no burning response
= 1 linear burning response
= 2 nonlinear burning response

NPRNT = 0 print time histories and profiles
= 1 time histories and profiles not printed

Inputs in INPUT. Subroutine INPUT reads the geometrical parameters; steady-state parameters; propellant, gas, and particle properties; and reference quantities needed to describe the motor under consideration. This information is given on the nine cards described below:

Card 1:

HEADER Alphanumeric heading

Card 2:

PIN = initial chamber pressure (atmospheres)

TFSTR = adiabatic flame temperature (deg R)

Card 3:

ELSTR = chamber length (ft)

RCHSTR = chamber radius (ft)

UT = Mach number at nozzle entrance

Card 4:

PRSTR = reference pressure in psi (normally 14.7)

TRSTR = reference temperature in deg R (normally 540.0)

RGAS = gas constant (ft-lbf)/(lbm-R)

GAM = specific heat ratio

Card 5:

SIGMA = particle diameter (microns)

SMDPC = ratio of particle mass flux to gas mass flux

NLDG = 0 linear drag law

= 1 nonlinear drag law

Card 6:

RHSSTR = density of the solid in lbm/ft^3

CSTR = specific heat of the solid in BTU/(lbm-R)

SKSSTR = conductivity of the solid in BTU/(ft-sec-R) x 10^{-5}

AES = activation energy of surface reaction in cal/mole

Card 7:

QWSTR = endothermic heat release at the surface in BTU/lbm

Card 8

CPSTR = specific heat of the gas in BTU/(lbm-R)

SKGSTR = conductivity of the gas in BTU/(ft-sec-R) x 10^{-5}

AEG = activation energy of the gas phase reaction in cal/mole

Card 9:

TSSTRR = reference temperature of surface in deg Rankine

SRS = surface regression rate in ft/sec

Note-- 0.0328 ft/sec = 1 cm/sec

PSURS = pressure (psi) at surface when TS = TSR and rate = SRS

CTS1 = initial guess of surface temperature (dimensionless)

The reference quantities PRSTR and TRSTR are normally associated with standard atmospheric conditions (14.7 psi, $540^{o}R$) which is the reference state used in nondimensionalizing the governing equations in the Kooker-Zinn analysis. The reference quantities TSSTRR, SRS, and PSURS are needed to define various constants in the equations describing the nonlinear transient combustion response; these must be obtained from experimental data.

Inputs in START. Subroutine START reads three additional control numbers, the initial disturbance amplitude, and the number of integration time-steps desired. These inputs are given on the three cards described below:

Card 1:

NSHØCK = 0 does not test for shocks

= 1 tests for shocks

ICTYPE = 1 Kookers continuous disturbance

= 2 initial first longitudinal mode

ISEN = 0 isothermal disturbance

= 1 isentropic disturbance

AMPL = half-amplitude of disturbance

Card 2:

NTIMES = number of integration time steps

Card 3:

HEADER = alphanumeric heading

In the description of ICTYPE, Kooker's continuous disturbance is a pulse-type perturbation with a maximum positive value at the head-end which smoothly declines to zero at about x = 1/3. For all of the cases considered in Volume I, the initial disturbance was an isentropic first longitudinal mode (ICTYPE = 2, ISEN = 1). Also the test for shocks was suppressed by choosing NSHØCK = 0.

Inputs in LØGIC. Subroutine LØGIC reads control parameters necessary for generating plotted output. These inputs are given on the four cards des ribed below:

Card 1:

LPLØT = 0 no plots produced

= 1 plotted output produced

NLAST = number of axial locations plotted

Card 2:

YMAX = maximum ordinate for pressure plots

DELY = interval of ordinate labeling for pressure plots

NTICY = number of ordinate tick marks for pressure plots

Card 3:

TMAX = maximum abscissa for pressure plots

DELT = interval of abscissa labeling for pressure plots

NTICT = number of abscissa tick marks for pressure plots

Card 4:

TMAX4 = maximum abscissa for amplitude plot

DELT4 = interval of abscissa labeling for amplitude plot

NTICT4 = number of abscissa tick marks for amplitude plot

If LPLØT = 0 the last three cards are omitted. The pressure plots are produced for the head-end, mid-chamber, and nozzle-end in that order. The number of plots desired is given by NLAST; thus, if all three plots are desired NLAST = 3, while if only the first plot is desired NLAST = 1. The ordinate for the pressure plots

is specified in terms of the normalized pressure perturbation $p'/\bar{p}$, and the corresponding abscissa is dimensionless time (using chamber sonic speed in normalizing); thus these units are used in specifying YMAX, DELY, TMAX, DELT, TMAX4, and DELT4. A centerline ($p'/\bar{p} = 0$) is provided if NTICY is specified as negative, and the ordinate range is $-\text{YMAX} \leq p'/\bar{p} \leq \text{YMAX}$. For the pressure amplitude versus time plot, the ordinate is the logarithm (base 10) of the normalized pressure perturbation; thus the ordinate range, labeling, and tick marks are fixed for all cases and are not specified in the input.

5.3 Description of the Subroutines

A brief description of each of the subroutines used in program KZM is given in this section, except GRAPHS, MYAXIS, MYLINE, AXLAB, and DENDEC which are the same as in the approximate programs.

SUBRØUTINE INPUT (NØPT, NT, T). The primary purpose of this subroutine is to read the motor parameters given above in the description of the input. After these parameters are read, several constants used in the linear and non-linear transient combustion models are evaluated. Next, a surface temperature TS is calculated which is compatible with the chamber pressure PIN; this computation is necessary if PIN differs from the reference pressure for the propellant PSURS. The solution for TS involves an iteration procedure using the subroutine ITSUB. Once the surface temperature is known, the initial temperature profiles and burning rates for the 11 burning stations are calculated using the steady-state equations. For linear combustion (NØPT = 1) the parameters A and B are calculated using Equations (97) and (98). This subroutine also prints out the input parameters, calculates and prints out the particle drag constants DGK (K) and DGKNL (K_{NL}), and prints out other calculated constants (see description of output).

SUBRØUTINE START (NØPT, NT, T, NPRNT). This subroutine first calculates the steady-state values of the chamber properties at each of the 25 equally spaced grid points. The following properties are calculated based on a constant-pressure, linear-velocity profile: gas density R(M,KS), pressure P(M,KS), entropy S(M,KS), sonic speed SSP(M,KS), axial gas velocity U(M,KS), particle density RP(M,KS), and particle velocity UP(M,KS). Also the gas and particle mass fluxes at the burning propellant surface (SMDG(M,KS) and SMDP(M,KS) respectively) are calculated for each of the 25 grid points using subroutine CØMBNT. In the above variables M is the index of the grid point and KS = 1 in this program.

After reading the parameters NSHØCK, ICTYPE, ISEN, AMPL, and NTIMES; the nozzle admittance (ADM), the mass balance (SMØUT and SMIN), and the frequency parameter (ØMEGA) are calculated. The steady-state profiles calculated previously are printed out (by calling subroutine ØUTPUT) along with ADM, SMØUT, SMIN, and ØMEGA. Next the initial disturbance is calculated (based on the parameters ICTYPE, ISEN, and AMPL) and added to the steady-state solutions to obtain the initial values of the chamber properties which are then printed out (again using subroutine ØUTPUT). Finally subroutine START calls subroutine LØGIC to perform the numerical solutions of the chamber conservation equations.

<u>SUBRØUTINE ØUTPUT (NT, T, KST, NPRNT)</u>. This subroutine produces most of the printed output generated by KZM. Two types of output are produced: (1) values of the calculated chamber properties at each of the 25 grid points for certain values of the dimensionless time and (2) values of the chamber properties at frequent time intervals for head-end, mid-chamber, and nozzle-end locations. These are described in more detail in the next section. The input variables NT and T are the time step index (integer) and the dimensionless time, respectively, while KST = 1 in this program. This subroutine also stores data in plotting arrays (YPLØT) for later plotting by GRAPHS (called by LØGIC). The data to be printed or stored for plotting is transferred by CØMMØN blocks (VARG and PLTVAR).

<u>SUBRØUTINE LØGIC (KST, NØPT, NPRNT)</u>. Subroutine LØGIC controls the numerical integration of the chamber conservation equations. The following operations are performed at each integration time-step (by means of a DØ loop):

(1) the integration time step-size DT is calculated using the Courant-Friedrichs-Lewy stability condition (Reference 3);

(2) a test for pressure maxima or minima is performed for NT > 3, if a maximum or minimum is found the peak-to-peak amplitude is calculated

(3) for NSHØCK ≠ 0, a test for shock-wave development is performed (subroutine SHDETL), if a shock-wave is detected current values are printed out and the job is terminated;

(4) boundary values are calculated at the head-end and nozzle end for the next time increment (subroutines BNDMØC and NØZMØC);

(5) values of the chamber variables are calculated at the interior grid points for the next time increment using subroutine TAYLØR;

(6) new values of the gas and particle fluxes at the burning propellant surface are calculated by subroutines NUTEMP and CØMBNT; and

(7) the calculated values of the chamber variables are printed out by subroutine ØUTPUT.

The numerical integrations are terminated when NT = NTIMES and the plotted output is produced by subroutine GRAPHS.

SUBRØUTINE BNDMØC (KST, MBC). Subroutine BNDMØC uses the method of characteristics to calculate the rigid wall boundary values at the head-end for a motor or at both ends for a closed-ended chamber (particles in a box). For MBC = -1 a left-hand boundary (head-end) is considered, while a right-hand boundary is considered for MBC = 1. In either case the rigid wall boundary conditions require that the gas and particle velocities are zero; these values are assigned and stored in UUD(MM,1) and UPUD(MM,1) respectively. The method of characteristics is then used to calculate the remaining variables: pressure, gas density, particle density, entropy, and sonic speed and stores them in PUD(MM,1), RUD(MM,1), RPUD(MM,1), SUD(MM,1), and SSPUD(MM,1) respectively. In these variables MM = 1 for a left-hand boundary and MM = 2 for a right-hand boundary. The boundary variables are transferred to subroutine LØGIC through CØMMØN block VARUPD.

SUBRØUTINE NØZMØC (KST). This subroutine uses the method of characteristics to calculate the boundary values at the nozzle-end of the rocket motor. In these calculations the gas velocity and pressure at the nozzle entrance are related by the quasi-steady nozzle admittance condition (i.e., Equations (91) and (92)). The calculated values of the pressure, gas density, particle density, gas velocity, particle velocity, entropy, and sonic speed are stored in the arrays PUD(2,1), RUD(2,1), RPUD(2,1), UUD(2,1), UPUD(2,1), SUD(2,1), and SSPUD (2,1) respectively. These values are transferred to subroutine LØGIC through CØMMØN block VARUPD.

SUBRØUTINE TAYLØR (KS). Subroutine TAYLØR calculates new values of the gas and particle densities, gas and particle velocities, and the entropy for all interior grid points by means of a Taylor series expansion in time. All spatial derivatives (first and second) needed in these calculations are determined using central differences. The pressure and sonic speed are calculated using the equation of state. The calculated values are returned to subroutine LØGIC through CØMMØN block VARG.

SUBRØUTINE NUTEMP (KST, NØPT, NT). Subroutine NUTEMP controls the calculation of the gas and particle mass fluxes at the burning propellant surface. To save computation time, the burning rate calculations are performed at fewer locations (11) than the number of grid points (25) used in the chamber calculations. Thus NUTEMP first determines the pressure at each of the 11 burning stations from the previously calculated values at the 25 grid points by means of linear interpolation. These values are stored in APLØC(IBS) where IBS is the burning station index. If the linear combustion option is selected (NØPT = 1), the pressure perturbation PDEL is calculated from APLØC(IBS) and subroutine LINTHW is called to compute the burning rate. For nonlinear combustion (NØPT = 2), the burning rate is calculated from APLØC(IBS) using subroutine THRMWV.

SUBRØUTINE THRMWV (IBS, PLOC, TFLM, NT). This subroutine determines the surface regression rate RGR(IBS) and the mass flux of gaseous combustion products FSMDG(IBS) at burning station IBS using the nonlinear Kooker-Zinn combustion model. For a given local pressure PLØC, the temperature profile in the solid is determined by solving the energy equation (i.e., Equation (3.20) of Reference 3) subject to the time-dependent heat transfer boundary condition (i.e., Equation (3.20b) of Reference 3) at the burning surface. Once the temperature profile is determined, the surface temperature is known and the regression rate and mass flow rate are obtained from the Arrhenius rate equation (Equations (3.21) and (3.22) of Reference 3).

The solution for the temperature profiles is accomplished by means of the method of invariant imbedding described in pp. 88-96 in Reference 3. The numerical solution is obtained using the algorithm given on pp. 95-96 of Reference 3, where the following nomenclature is used in THRMWV: $\theta(y)$ is denoted by CNU(J,IBS), $v(y)$ by SV(J,IBS), $w(y)$ by SW(J,IBS), and $\hat{T}(y)$ by CT(J,IBS). The time-dependent boundary condition at the propellant surface is satisfied by using an iterative procedure which calls subroutine ITSUB.

SUBRØUTINE LINTHW (IBS, PDEL). This subroutine determines the surface regression rate RGR(IBS) and the mass flux FSMDG(IBS) using the linearized version of the Kooker-Zinn combustion model described in Section 3.2 of Volume I. In this case the temperature profiles in the solid propellant are obtained by using the method of invariant imbedding to solve Equations (93) through (96). The numerical calculations are performed using an algorithm similar to that used by THRMWV, and the nomenclature is the same as in THRMWV. The pressure PDEL which must be specified when LINTHW is called is the perturbation obtained

by subtracting the steady-state pressure form the local pressure.

SUBRØUTINE CØMBNT (XND, KS, KST, HAFL, SMDGL, SMDPL). Subroutine CØMBNT calculates the gas mass flow rate SMDGL and the particle mass flow rate SMDPL emerging from the burning propellant surface at the axial location specified by XND. The value of SMDGL is obtained by linear interpolation from the previously calculated values of FSMDG(IBS) at the 11 burning stations. The corresponding value of SMDPL is determined by multiplying SMDGL by the particle loading SMDPC. The axial location XND is specified in terms of the dimensionless axial coordinate ξ which is -1 at the head-end and zero at the nozzle end. The dimensionless adiabatic flame enthalpy HAFL is also calculated (in this program it is simply the constant value HAFC). The values of FSMDG, SMDPC, and HAFC needed for these calculations are obtained through CØMMØN blocks MSFSLD and CØMFIX.

SUBRØUTINE MØCINT (Y1, Y2, Y3, DXN, Y0). This subroutine determines the value of the function Y0 at the intermediate location specified by DXN from the values of the function Y1, Y2, Y3 at three equally spaced grid points. This is done using the standard three-point interpolation formula, where DXN is measured from the left-most point (i.e,, Y1) in terms of the grid-spacing DX. Subroutine MØCINT is called by subroutines BNDMØC and NØZMØC to obtain interpolated values of various chamber properties needed in the method of characteristics solutions.

SUBRØUTINE SHDETL (U1, U2, U3, U4, SHDET, NYES). This subroutine tests for shock-wave formation using the values of the pressure at four grid points specified by U1, U2, U3, and U4. This calculation is performed using a polynomial fitting technique described on pp. 64-67 of Reference 3, where an infinite gradient indicates shock-wave formation. If a shock-wave is detected, SHDETL returns NYES = 1, otherwise NYES = 0. The value of the discriminant $\tilde{D}$ given by Equation (2.50) of Reference 3 is also calculated as SHDET.

SUBRØUTINE ITSUB(FØFY, Y, SAVE, CØNV, NTIMES). This subroutine obtains the solution of the equation F(y) = 0 by an iterative technique. Here FØFY is the value of the function F corresponding to a guess of the solution Y, and SAVE is a one-dimensional array of eight locations. Beginning with an initial guess for Y, ITSUB changes Y in subsequent iterations in such a manner as to drive FØFY to zero (within a specified tolerance). Thus the final value of Y calculated is the desired root of the equation F(y) = 0. The maximum number of iterations permitted is specified by NTIMES. Furthermore SAVE(1) = 1 and SAVE(2) is the initial increment used in changing Y. Convergence to the desired root is

indicated by the value of SAVE(1) returned: 1 $\leq$ SAVE(1) $\leq$ 4 indicates that further iterations are required; SAVE(1) = 5 indicates convergence to the required root, and SAVE(1) = 6 indicates that convergence did not occur within the specified number of iterations.

5.4 Description of Output

Program KZM produces printed output with an option to produce plotted output if desired.

Printed Output. The printed output is given in six major sections: (1) restatement of input parameters, (2) motor geometry and burning rates, (3) steady-state profiles, (4) initial disturbance profiles, (5) time histories of pressures, gas and particle velocities, and burning rates, and (6) profiles of chamber properties at selected time intervals.

Section (1), which occupies the first page, gives the following input parameters: (1) chamber pressure in atmospheres, (2) chamber length and radius in feet, (3) nozzle entrance Mach number, (4) surface heat release in BTU/lbm, (5) reference surface properties (temperature in ^{o}R, regression rate in ft/sec, and pressure in psi), and (6) particle properties. The last of these includes the calculated values of the linear and nonlinear drag constants.

In addition a number of calculated quantities are given. Most of these relate to the Kooker-Zinn transient combustion model (i.e., QFSTR, BIGK, YHC, BRAY, BR, WCØN, WSTRR, EØRG,EØRS, ETF, ACØN, QMC, Z1H, Z2H, WSTRS, Z1, and Z2P) and are not of interest to the general user. The remaining quantities in this group are defined as follows: TF is the normalized flame temperature, TS is the normalized surface temperature, R is the dimensionless surface regression rate (used to calculate Ω), DXSBS is the axial spacing between burning stations, ARSTR is the reference speed of sound in ft/sec, and RHRSTR is the reference density in lbm/ft^3. Finally the linear combustion parameters A and B are given if the linear combustion option (NØPT = 1) is selected.

Section (2) is given on the next two pages. The first of these describes the motor geometry and coordinate system, while the second gives the initial burning rates. These are tabulated according to the index M for each of the 25 grid points (M=1 at the head-end and M=25 at the nozzle-end). The variables tabulated on the first page are described as follows: CAP X is the dimensionless axial coordinate (i.e., X of Reference 3), XI is X-1, X STR is the axial location of the grid point in feet (measured from the nozzle-end of the chamber),

RWALL is the local chamber radius in feet, DRWDX is the axial derivative of RWALL, AREA is the chamber cross-sectional area in ft^2, DLNADX is the logarithmic derivative of AREA, and RW2 is $2L^*/R^*$ which is four times the length-to-diameter ratio. The second page gives the dimensionless mass burning rates of the gas, SMDG, and particles , SMDP, as well as the dimensionless chamber enthalpy (or temperature), HAF.

Section (3) gives the steady-state profiles in tabular form. For each of the 25 grid points (index M) the following variables are given: the axial coordinate (X STR), Mach number, pressure, density, axial velocity, entropy, enthalpy, local sound speed (A(LØC)), particle density, particle velocity, mass burning rate of gas (SMDG) and particles (SMDP), and time derivative of the gas burning rate (SMDDG). This is followed by a tabulation of the following properties at each of the 11 burning stations (index IBS): mass burning rate for gas (F SMDG), dimensionless regression rate (R), surface temperature, and local pressure. Finally the mass balance, dimensionless frequency parameter Ω and the nozzle parameters are given. Here MASS IN is the total flux of burned gases leaving the propellant surface, and MASS OUT is the mass flux through the nozzle entrance plane; the steady-state solutions must be chosen such that these mass fluxes are equal. UBAR and PBAR are the axial velocity and pressure at the nozzle entrance plane, which are used to compute the quasi-steady nozzle admittance ADM. TCØNV is the factor relating the dimensionless time used in the "exact" analysis (based on standard atmospheric conditions) to the dimensionless time used in the approximate analysis (based on chamber conditions); it is the ratio of sound speeds for these two reference states.

Section (4) gives the initial values of the chamber properties in the same format as Section (3). These values are the sum of the steady-state values given in Section (3) and the initial disturbance perturbations calculated in subroutine START.

Section (5) gives the time histories of the most important chamber properties in tabular form. The first column gives the index of the integration time step, where only even numbered steps are printed. The second column gives the dimensionless time, where the upper value is based on standard atmospheric conditions and the lower value is based on chamber stagnation conditions. The next three columns give the pressure at the head-end (P(1)), the mid-chamber (P(13)), and the nozzle-end (P(25)). The upper value is the total pressure (i.e., steady-state plus perturbation) in atmospheres, and the lower value is the pressure

perturbation normalized by the steady-state pressure. The sixth column gives the dimensionless axial gas velocity (sum of steady-state and perturbation) at the nozzle-end (U(25)) and at the chamber midpoint (U(13)), while the Mach number at the nozzle entrance (M(25)) and the particle velocity at the midpoint (UP(13)) are given in the seventh column. The last column gives the burning rate perturbation normalized by the steady-state burning rate for both the head-end (MG(1)) and the nozzle-end (MG(25)).

Information about the head-end pressure maxima and minima is also given in Section (5). For each maximum or minimum the following information is given: the index of the maximum or minimum (NPMAX), the dimensionless time (based on chamber conditions) at which the extremum occurs (TMAX), the corresponding value of the head-end pressure perturbation (PMAX), the peak-to-peak pressure amplitude, the mean time for the half-cycle (T), and the mean pressure perturbation (PMEAN). The last two quantities are arithmetic averages of the time and pressure at the current extremum and the immediately preceding extremum. If the printout of the time-histories is suppressed (NPRNT = 1), only the maxima and minima are printed in Section (5).

Finally Section (6) gives the profiles of the chamber properties at selected time intervals in the same format as Sections (3) and (4). These profiles are printed every 100 time-steps. For NPRNT = 1 these profiles are not printed.

Plotted Output. For LPLØT = 1 plotted output is produced using a Calcomp plotter. The format of the plots is the same as that described for the approximate programs (i.e., SOLID2, MA2 and TB2). The first three plots give the normalized pressure perturbation versus dimensionless time (chamber conditions) for the head-end, mid-chamber, and nozzle-end. These plots can be compared directly with similar plots produced by the approximate programs. The last plot produced gives peak-to-peak pressure amplitude versus dimensionless time, where the amplitude is plotted on a logarithmic scale.

Sample Case. A test case is given to illustrate the operation of Program KZM and facilitate check-out of the program. This case corresponds to the nonlinear drag case (NLDG = 1) shown in Figure 46 of Volume I: 20 micron particles at 36% loading. The linear combustion option is selected (NØPT = 1) with QWSTR = - 250.9 BTU/lbm ($Q_s^* = -139.4$ cal/gm) which corresponds to $A = 5.996$, $B = 0.550$, and $n = 0.552$. The gas phase and propellant properties (i.e., TFSTR, GAM, RHSSTR,

CSTR, SKSSTR, AES, CPSTR, SKGSTR, and AEG) are taken from Table 1 of Volume I. The motor geometry considered in Volume I is also specified; the motor length (ELSTR) is 1.958 ft and the chamber radius (RCHSTR) is 0.099285 ft. The reference quantities used in non-dimensionalizing the various chamber properties are the standard atmospheric quantities (PRSTR = 14.7 psi and TRSTR = 540^{o}R), while the reference properties needed to characterize the propellant are TSSTRR = 1440^{o}R, SRS = 0.03827 ft/sec and PSURS = 1568 psi. The initial guess of the normalized surface temperature is based on the above value, thus CTS1 = 2.67. The initial disturbance is assumed to be a fundamental mode, isentropic disturbance (ICTYPE = 2, ISEN = 1) of 5% amplitude (AMPL = 0.05). The program is run for 400 integration time steps which gives printed output for dimensionless times (based on chamber conditions) of $0 \leq t \leq 12.3$ and plotted output for $0 \leq t \leq 10.0$.

The input for this case is shown in the proper format on the following page. This is followed by the resulting printed and plotted output.

```
    1    0
TEST CASE FØR KZM
     106.7    6345.0
     1.958  0.099285  0.078041
      14.7     540.0      70.0      1.23
      20.0      0.36    1
    110.25     0.329      3.90   15250.0
    -250.9
     0.483     3.610   30000.0
    1440.0   0.03827    1568.0      2.67
    0    2    1       0.05
  400
LINEAR CØMB. RESP., 20.0 MICRØN PARTICLES, 0.05 AMPL.
    1    3
      0.10      0.02 -101
      10.0       2.0   51
      10.0       2.0   51
```

```
TEST CASE FOR KZM

INITIAL CHAMBER PRESSURE =        106.7

          CHAMBER LENGTH =        1.958
          CHAMBER RADIUS =       .099285
NOZZLE ENTRANCE MACH NO. =       .07804

    SURFACE HEAT RELEASE =       -250.9

   REF. SURFACE TEMPERATURE =     1440.0
REF. SURFACE REGRESSION RATE =    .03827
      REF. SURFACE PRESSURE =     1568.0

       PARTICLE DIAMETER =        20.00  MICRONS
           DRAG CONSTANT =        1.602
      N.L. DRAG CONSTANT =        2.969
               SMOP/SMOG =        .3600

QFSTR(BTU/LBM)= .24143150E+04   BASED ON (QMSTR,TCSSTR,CFSTR,CSTR,TF,TSR) OF
 -.25090000E+03  .54000000E+03  .48300000E+00  .32900000E+00  .11750000E+02  .26666667E+01
BIGK= .44873812E-09   YHC= .21184856E-04   BRAY= .21659966E+05   BR= .56144818E+03   WCON= .28402314E+02   WSTRR= .44592164E+04
EORG= .50327126E+02   EORS= .25582956E+02   TF= .11750000E+02   TS= .26667228E+01   ETF= .13798993E-01
R= .14767063E+01  ACON= .16667228E+01  QMC= .41707685E-01   Z1M=-.14122481E+01  Z2PH= .12436648E-03   WSTRS= .44620039E+04
Z1=-.30589246E+05  Z2P= .57417670E-08  DXSBS= .19580000E+00  ARSTR= .12235632E+04  RHRSTR= .56000000E-01

     LINEAR COMBUSTION PARAMETERS          A =   5.996     B =    .550
```

SMB = -1.00000   SMC = 0.00000   CMB = 1.00000

M	CAP X	XI	X STR	RWALL	DRWDX	AREA	DLNADX	RW2
1	0.	-.10000E+01	-.19580E+01	.99285E-01	0.	.30968E-01	0.	.39442E+02
2	.41667E-01	-.95833E+00	-.18764E+01	.99285E-01	0.	.30968E-01	0.	.39442E+02
3	.83333E-01	-.91667E+00	-.17948E+01	.99285E-01	0.	.30968E-01	0.	.39442E+02
4	.12500E+00	-.87500E+00	-.17133E+01	.99285E-01	0.	.30968E-01	0.	.39442E+02
5	.16667E+00	-.83333E+00	-.16317E+01	.99285E-01	0.	.30968E-01	0.	.39442E+02
6	.20833E+00	-.79167E+00	-.15501E+01	.99285E-01	0.	.30968E-01	0.	.39442E+02
7	.25000E+00	-.75000E+00	-.14685E+01	.99285E-01	0.	.30968E-01	0.	.39442E+02
8	.29167E+00	-.70833E+00	-.13869E+01	.99285E-01	0.	.30968E-01	0.	.39442E+02
9	.33333E+00	-.66667E+00	-.13053E+01	.99285E-01	0.	.30968E-01	0.	.39442E+02
10	.37500E+00	-.62500E+00	-.12238E+01	.99285E-01	0.	.30968E-01	0.	.39442E+02
11	.41667E+00	-.58333E+00	-.11422E+01	.99285E-01	0.	.30968E-01	0.	.39442E+02
12	.45833E+00	-.54167E+00	-.10606E+01	.99285E-01	0.	.30968E-01	0.	.39442E+02
13	.50000E+00	-.50000E+00	-.97900E+00	.99285E-01	0.	.30968E-01	0.	.39442E+02
14	.54167E+00	-.45833E+00	-.89742E+00	.99285E-01	0.	.30968E-01	0.	.39442E+02
15	.58333E+00	-.41667E+00	-.81583E+00	.99285E-01	0.	.30968E-01	0.	.39442E+02
16	.62500E+00	-.37500E+00	-.73425E+00	.99285E-01	0.	.30968E-01	0.	.39442E+02
17	.66667E+00	-.33333E+00	-.65267E+00	.99285E-01	0.	.30968E-01	0.	.39442E+02
18	.70833E+00	-.29167E+00	-.57108E+00	.99285E-01	0.	.30968E-01	0.	.39442E+02
19	.75000E+00	-.25000E+00	-.48950E+00	.99285E-01	0.	.30968E-01	0.	.39442E+02
20	.79167E+00	-.20833E+00	-.40792E+00	.99285E-01	0.	.30968E-01	0.	.39442E+02
21	.83333E+00	-.16667E+00	-.32633E+00	.99285E-01	0.	.30968E-01	0.	.39442E+02
22	.87500E+00	-.12500E+00	-.24475E+00	.99285E-01	0.	.30968E-01	0.	.39442E+02
23	.91667E+00	-.83333E-01	-.16317E+00	.99285E-01	0.	.30968E-01	0.	.39442E+02
24	.95833E+00	-.41667E-01	-.81583E-01	.99285E-01	0.	.30968E-01	0.	.39442E+02
25	.10000E+01	0.	0.	.99285E-01	0.	.30968E-01	0.	.39442E+02

M	SMGG	SMOF	HAF
1	.61590E-01	.22172E-01	.11750E+02
2	.61590E-01	.22172E-01	.11750E+02
3	.61590E-01	.22172E-01	.11750E+02
4	.61590E-01	.22172E-01	.11750E+02
5	.61590E-01	.22172E-01	.11750E+02
6	.61590E-01	.22172E-01	.11750E+02
7	.61590E-01	.22172E-01	.11750E+02
8	.61590E-01	.22172E-01	.11750E+02
9	.61590E-01	.22172E-01	.11750E+02
10	.61590E-01	.22172E-01	.11750E+02
11	.61590E-01	.22172E-01	.11750E+02
12	.61590E-01	.22172E-01	.11750E+02
13	.61590E-01	.22172E-01	.11750E+02
14	.61590E-01	.22172E-01	.11750E+02
15	.61590E-01	.22172E-01	.11750E+02
16	.61590E-01	.22172E-01	.11750E+02
17	.61590E-01	.22172E-01	.11750E+02
18	.61590E-01	.22172E-01	.11750E+02
19	.61590E-01	.22172E-01	.11750E+02
20	.61590E-01	.22172E-01	.11750E+02
21	.61590E-01	.22172E-01	.11750E+02
22	.61590E-01	.22172E-01	.11750E+02
23	.61590E-01	.22172E-01	.11750E+02
24	.61590E-01	.22172E-01	.11750E+02
25	.61590E-01	.22172E-01	.11750E+02

THE FOLLOWING FLOW FIELD WAS READ IN ON CARDS FROM A PREVIOUS COMPUTATION

TEST CASE FOR KZM

COMPUTATION STEP(0) WHERE TIME(NON-DIMENSIONAL)= 0. DT= 0. T(MIL-SEC)= 0.

REGION(1) WHERE SMB= -.10000E+01 SMC= 0. CMB= .10000E+01

INDEX M	X STR	MACH NO.	PRESSURE	DENSITY	VELOCITY	ENTROPY	ENTHALPY	A(LOC)
1	-.195800E+01	0.	.106700E+03	.908085E+01	0.	.195643E+01	.117500E+02	.342783E+01
2	-.187642E+01	.325171E-02	.106700E+03	.908085E+01	.111463E-01	.195643E+01	.117500E+02	.342783E+01
3	-.179483E+01	.650342E-02	.106700E+03	.908085E+01	.222926E-01	.195643E+01	.117500E+02	.342783E+01
4	-.171325E+01	.975513E-02	.106700E+03	.908085E+01	.334389E-01	.195643E+01	.117500E+02	.342783E+01
5	-.163167E+01	.130068E-01	.106700E+03	.908085E+01	.445852E-01	.195643E+01	.117500E+02	.342783E+01
6	-.155008E+01	.162585E-01	.106700E+03	.908085E+01	.557315E-01	.195643E+01	.117500E+02	.342783E+01
7	-.146850E+01	.195103E-01	.106700E+03	.908085E+01	.668778E-01	.195643E+01	.117500E+02	.342783E+01
8	-.138692E+01	.227620E-01	.106700E+03	.908085E+01	.780241E-01	.195643E+01	.117500E+02	.342783E+01
9	-.130533E+01	.260137E-01	.106700E+03	.908085E+01	.891704E-01	.195643E+01	.117500E+02	.342783E+01
10	-.122375E+01	.292654E-01	.106700E+03	.908085E+01	.100317E+00	.195643E+01	.117500E+02	.342783E+01
11	-.114217E+01	.325171E-01	.106700E+03	.908085E+01	.111463E+00	.195643E+01	.117500E+02	.342783E+01
12	-.106058E+01	.357688E-01	.106700E+03	.908085E+01	.122609E+00	.195643E+01	.117500E+02	.342783E+01
13	-.979000E+00	.390205E-01	.106700E+03	.908085E+01	.133756E+00	.195643E+01	.117500E+02	.342783E+01
14	-.897417E+00	.422722E-01	.106700E+03	.908085E+01	.144902E+00	.195643E+01	.117500E+02	.342783E+01
15	-.815833E+00	.455239E-01	.106700E+03	.908085E+01	.156048E+00	.195643E+01	.117500E+02	.342783E+01
16	-.734250E+00	.487756E-01	.106700E+03	.908085E+01	.167194E+00	.195643E+01	.117500E+02	.342783E+01
17	-.652667E+00	.520273E-01	.106700E+03	.908085E+01	.178341E+00	.195643E+01	.117500E+02	.342783E+01
18	-.571083E+00	.552790E-01	.106700E+03	.908085E+01	.189487E+00	.195643E+01	.117500E+02	.342783E+01
19	-.489500E+00	.585308E-01	.106700E+03	.908085E+01	.200633E+00	.195643E+01	.117500E+02	.342783E+01
20	-.407917E+00	.617825E-01	.106700E+03	.908085E+01	.211780E+00	.195643E+01	.117500E+02	.342783E+01
21	-.326333E+00	.650342E-01	.106700E+03	.908085E+01	.222926E+00	.195643E+01	.117500E+02	.342783E+01
22	-.244750E+00	.682859E-01	.106700E+03	.908085E+01	.234072E+00	.195643E+01	.117500E+02	.342783E+01
23	-.163167E+00	.715376E-01	.106700E+03	.908085E+01	.245218E+00	.195643E+01	.117500E+02	.342783E+01
24	-.815833E-01	.747893E-01	.106700E+03	.908085E+01	.256365E+00	.195643E+01	.117500E+02	.342783E+01
25	0.	.780410E-01	.106700E+03	.908085E+01	.267511E+00	.195643E+01	.117500E+02	.342783E+01

INDEX OF DISCONTINUITY DIRECTION= 0 AND DISCONTINUITY LOCATION= 0.

INDEX M	X STR	PARTICLE DENSITY	PARTICLE VELOCITY	SMDG	SMDP	SMDDG
1	-.195800E+01	.413257E+01	0.	.615900E-01	.221724E-01	0.
2	-.187642E+01	.413257E+01	.881738E-02	.615900E-01	.221724E-01	0.
3	-.179483E+01	.413257E+01	.176348E-01	.615900E-01	.221724E-01	0.
4	-.171325E+01	.413257E+01	.264521E-01	.615900E-01	.221724E-01	0.
5	-.163167E+01	.413257E+01	.352695E-01	.615900E-01	.221724E-01	0.
6	-.155008E+01	.413257E+01	.440869E-01	.615900E-01	.221724E-01	0.
7	-.146850E+01	.413257E+01	.529043E-01	.615900E-01	.221724E-01	0.
8	-.138692E+01	.413257E+01	.617217E-01	.615900E-01	.221724E-01	0.
9	-.130533E+01	.413257E+01	.705391E-01	.615900E-01	.221724E-01	0.
10	-.122375E+01	.413257E+01	.793564E-01	.615900E-01	.221724E-01	0.
11	-.114217E+01	.413257E+01	.881738E-01	.615900E-01	.221724E-01	0.
12	-.106058E+01	.413257E+01	.969912E-01	.615900E-01	.221724E-01	0.
13	-.979000E+00	.413257E+01	.105809E+00	.615900E-01	.221724E-01	0.
14	-.897417E+00	.413257E+01	.114626E+00	.615900E-01	.221724E-01	0.
15	-.815833E+00	.413257E+01	.123443E+00	.615900E-01	.221724E-01	0.
16	-.734250E+00	.413257E+01	.132261E+00	.615900E-01	.221724E-01	0.
17	-.652667E+00	.413257E+01	.141078E+00	.615900E-01	.221724E-01	0.
18	-.571083E+00	.413257E+01	.149895E+00	.615900E-01	.221724E-01	0.
19	-.489500E+00	.413257E+01	.158713E+00	.615900E-01	.221724E-01	0.
20	-.407917E+00	.413257E+01	.167530E+00	.615900E-01	.221724E-01	0.
21	-.326333E+00	.413257E+01	.176348E+00	.615900E-01	.221724E-01	0.
22	-.244750E+00	.413257E+01	.185165E+00	.615900E-01	.221724E-01	0.
23	-.163167E+00	.413257E+01	.193982E+00	.615900E-01	.221724E-01	0.
24	-.815833E-01	.413257E+01	.202800E+00	.615900E-01	.221724E-01	0.
25	0.	.413257E+01	.211617E+00	.615900E-01	.221724E-01	0.

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IBS       XSTEPS         F SMOG          R           TEMP SUR.      PRESS(LOC)
  1   -.195800E+01  .615900E-01  .147671E+01  .266672E+01  .106700E+03
  2   -.176220E+01  .615900E-01  .147671E+01  .266672E+01  .106700E+03
  3   -.156640E+01  .615900E-01  .147671E+01  .266672E+01  .106700E+03
  4   -.137060E+01  .615900E-01  .147671E+01  .266672E+01  .106700E+03
  5   -.117480E+01  .615900E-01  .147671E+01  .266672E+01  .106700E+03
  6   -.979000E+00  .615900E-01  .147671E+01  .266672E+01  .106700E+03
  7   -.783200E+00  .615900E-01  .147671E+01  .266672E+01  .106700E+03
  8   -.587400E+00  .615900E-01  .147671E+01  .266672E+01  .106700E+03
  9   -.391600E+00  .615900E-01  .147671E+01  .266672E+01  .106700E+03
 10   -.195800E+00  .615900E-01  .147671E+01  .266672E+01  .106700E+03
 11    0.           .615900E-01  .147671E+01  .266672E+01  .106700E+03
STEP(   0)  T=  0.000000  P(1)=106.700000  P(13)=106.700000  P(25)=106.700000  U(25)=   .267511  M(25)=   .070041  MG(1)=  0.000000
            0.000000        0.000000          0.000000          0.000000  U(13)=   .133756  UP(13)=  .105009  MG(25)= 0.000000

MASS BALANCE (LBM/SEC):     MASS IN =    5.1547     MASS OUT =    5.1547

OMEGA =  4.9383


UBAR =    .267511    PBAR =  106.7000    ADM =    .000234    TCONV =  3.427827

THE RESTARTED FLOW FIELD CONTAINING THE ADDED DISTURBANCE FOLLOWS
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LINEAR COMB. RESP., 20.0 MICRON PARTICLES, 0.05 AMPL.

COMPUTATION STEP(0) WHERE TIME(NON-DIMENSIONAL)= 0. DT= 0. T(MIL-SEC)= 0.

REGION(1) WHERE SMB= -.10000E+01 SMC= 0. CMB= .10000E+01

INDEX M	X STR	MACH NO.	PRESSURE	DENSITY	VELOCITY	ENTROPY	ENTHALPY	A(LOC)
1	-.195900E+01	0.	.112035E+03	.944830E+01	0.	.195643E+01	.118577E+02	.344350E+01
2	-.187642E+01	.323703E-02	.111999E+03	.944517E+01	.111463E-01	.195643E+01	.118568E+02	.344337E+01
3	-.179483E+01	.647400E-02	.111853E+03	.943583E+01	.222926E-01	.195643E+01	.118541E+02	.344298E+01
4	-.171325E+01	.971402E-02	.111629E+03	.942045E+01	.334389E-01	.195643E+01	.118496E+02	.344233E+01
5	-.163167E+01	.129554E-01	.111320E+03	.939926E+01	.445852E-01	.195643E+01	.118435E+02	.344144E+01
6	-.155008E+01	.161995E-01	.110933E+03	.937264E+01	.557315E-01	.195643E+01	.118358E+02	.344032E+01
7	-.146850E+01	.194470E-01	.110472E+03	.934102E+01	.668778E-01	.195643E+01	.118266E+02	.343898E+01
8	-.138692E+01	.226982E-01	.109948E+03	.930494E+01	.780241E-01	.195643E+01	.118161E+02	.343745E+01
9	-.130533E+01	.259537E-01	.109367E+03	.926439E+01	.891704E-01	.195643E+01	.118044E+02	.343575E+01
10	-.122375E+01	.292136E-01	.108742E+03	.922196E+01	.100317E+00	.195643E+01	.117917E+02	.343391E+01
11	-.114217E+01	.324780E-01	.108081E+03	.917629E+01	.111463E+00	.195643E+01	.117783E+02	.343195E+01
12	-.106058E+01	.357470E-01	.107396E+03	.912900E+01	.122609E+00	.195643E+01	.117643E+02	.342991E+01
13	-.979000E+00	.390205E-01	.106700E+03	.908085E+01	.133756E+00	.195643E+01	.117500E+02	.342783E+01
14	-.897417E+00	.422981E-01	.106004E+03	.903264E+01	.144902E+00	.195643E+01	.117356E+02	.342573E+01
15	-.815833E+00	.455794E-01	.105319E+03	.898519E+01	.156048E+00	.195643E+01	.117214E+02	.342366E+01
16	-.734250E+00	.488638E-01	.104658E+03	.893933E+01	.167194E+00	.195643E+01	.117076E+02	.342164E+01
17	-.652667E+00	.521506E-01	.104032E+03	.889585E+01	.178341E+00	.195643E+01	.116945E+02	.341972E+01
18	-.571083E+00	.554390E-01	.103452E+03	.885549E+01	.189487E+00	.195643E+01	.116823E+02	.341794E+01
19	-.489500E+00	.587281E-01	.102928E+03	.881895E+01	.200633E+00	.195643E+01	.116712E+02	.341631E+01
20	-.407917E+00	.620167E-01	.102467E+03	.878689E+01	.211780E+00	.195643E+01	.116614E+02	.341488E+01
21	-.326333E+00	.653039E-01	.102080E+03	.875985E+01	.222926E+00	.195643E+01	.116531E+02	.341367E+01
22	-.244750E+00	.685885E-01	.101771E+03	.873831E+01	.234072E+00	.195643E+01	.116465E+02	.341270E+01
23	-.163167E+00	.718694E-01	.101547E+03	.872265E+01	.245218E+00	.195643E+01	.116417E+02	.341200E+01
24	-.815833E-01	.751457E-01	.101411E+03	.871314E+01	.256365E+00	.195643E+01	.116388E+02	.341157E+01
25	0.	.784162E-01	.101365E+03	.870995E+01	.267511E+00	.195643E+01	.116378E+02	.341143E+01

INDEX OF DISCONTINUITY DIRECTION= 0 AND DISCONTINUITY LOCATION= 0.

INDEX M	X STR	PARTICLE DENSITY	PARTICLE VELOCITY	SMDG	SMDP	SMDDG
1	-.195800E+01	.413257E+01	0.	.615900E-01	.221724E-01	0.
2	-.187642E+01	.413257E+01	.881738E-02	.615900E-01	.221724E-01	0.
3	-.179483E+01	.413257E+01	.176348E-01	.615900E-01	.221724E-01	0.
4	-.171325E+01	.413257E+01	.264521E-01	.615900E-01	.221724E-01	0.
5	-.163167E+01	.413257E+01	.352695E-01	.615900E-01	.221724E-01	0.
6	-.155008E+01	.413257E+01	.440869E-01	.615900E-01	.221724E-01	0.
7	-.146950E+01	.413257E+01	.529043E-01	.615900E-01	.221724E-01	0.
8	-.138692E+01	.413257E+01	.617217E-01	.615900E-01	.221724E-01	0.
9	-.130533E+01	.413257E+01	.705391E-01	.615900E-01	.221724E-01	0.
10	-.122375E+01	.413257E+01	.793564E-01	.615900E-01	.221724E-01	0.
11	-.114217E+01	.413257E+01	.881738E-01	.615900E-01	.221724E-01	0.
12	-.106058E+01	.413257E+01	.969912E-01	.615900E-01	.221724E-01	0.
13	-.979000E+00	.413257E+01	.105809E+00	.615900E-01	.221724E-01	0.
14	-.897417E+00	.413257E+01	.114626E+00	.615900E-01	.221724E-01	0.
15	-.815833E+00	.413257E+01	.123443E+00	.615900E-01	.221724E-01	0.
16	-.734250E+00	.413257E+01	.132261E+00	.615900E-01	.221724E-01	0.
17	-.652667E+00	.413257E+01	.141078E+00	.615900E-01	.221724E-01	0.
18	-.571083E+00	.413257E+01	.149895E+00	.615900E-01	.221724E-01	0.
19	-.489500E+00	.413257E+01	.158713E+00	.615900E-01	.221724E-01	0.
20	-.407917E+00	.413257E+01	.167530E+00	.615900E-01	.221724E-01	0.
21	-.326333E+00	.413257E+01	.176348E+00	.615900E-01	.221724E-01	0.
22	-.244750E+00	.413257E+01	.185165E+00	.615900E-01	.221724E-01	0.
23	-.163167E+00	.413257E+01	.193982E+00	.615900E-01	.221724E-01	0.
24	-.815833E-01	.413257E+01	.202800E+00	.615900E-01	.221724E-01	0.
25	0.	.413257E+01	.211617E+00	.615900E-01	.221724E-01	0.

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  IBS       XSTRPS        F SMOG          R          TEMP SUR.     PRESS(LOC)
    1   -.195800E+01  .615900E-01  .147671E+01  .266672E+01  .112035E+03
    2   -.176220E+01  .615900E-01  .147671E+01  .266672E+01  .111763E+03
    3   -.156640E+01  .615900E-01  .147671E+01  .266672E+01  .111010E+03
    4   -.137060E+01  .615900E-01  .147671E+01  .266672E+01  .109832E+03
    5   -.117480E+01  .615900E-01  .147671E+01  .266672E+01  .108345E+03
    6   -.979000E+00  .615900E-01  .147671E+01  .266672E+01  .106700E+03
    7   -.783200E+00  .615900E-01  .147671E+01  .266672E+01  .105055E+03
    8   -.587400E+00  .615900E-01  .147671E+01  .266672E+01  .103568E+03
    9   -.391600E+00  .615900E-01  .147671E+01  .266672E+01  .102390E+03
   10   -.195800E+00  .615900E-01  .147671E+01  .266672E+01  .101637E+03
   11   0.            .615900E-01  .147671E+01  .266672E+01  .101365E+03
STEP(   0) T= 0.000000 P(1)=112.035000 P(13)=106.700000 P(25)=101.365000 U(25)=  .267511  M(25)=  .070416  MG(1)=  0.000000
          0.000000          .050000          -.000000          -.050000 U(13)=  .133756 UP(13)=  .105009 MG(25)= 0.000000

ERROR IN NOZPOC      21 .10137173E+03 .10137162E+03
STEP(   2) T=  .017960 P(1)=111.914713 P(13)=106.745346 P(25)=101.392452 U(25)=  .266267  M(25)=  .070047  PG(1)=   .031744
           .061591          .048873           .000425          -.049743 U(13)=  .157686 UP(13)=  .107823 MG(25)=  -.032160
STEP(   4) T=  .035941 P(1)=111.639252 P(13)=106.797292 P(25)=101.572755 U(25)=  .266309  M(25)=  .070045  MG(1)=   .051514
           .123201          .046291           .000912          -.048053 U(13)=  .179245 UP(13)=  .112015 MG(25)=  -.052811
STEP(   6) T=  .053919 P(1)=111.220266 P(13)=106.850752 P(25)=101.942986 U(25)=  .266396  M(25)=  .070042  PG(1)=   .066065
           .184826          .042364           .001413          -.044583 U(13)=  .197814 UP(13)=  .118118 MG(25)=  -.068351
STEP(   8) T=  .071903 P(1)=110.684211 P(13)=106.900639 P(25)=102.472028 U(25)=  .266520  M(25)=  .070039  MG(1)=   .075589
           .246473          .037340           .001880          -.039625 U(13)=  .213020 UP(13)=  .125505 MG(25)=  -.078745
STEP(  10) T=  .089851 P(1)=110.060385 P(13)=106.942685 P(25)=103.127416 U(25)=  .266674  M(25)=  .070036  MG(1)=   .080011
           .308132          .031434           .002274          -.033483 U(13)=  .224663 UP(13)=  .133019 MG(25)=  -.083740
STEP(  12) T=  .107866 P(1)=109.370294 P(13)=106.974008 P(25)=103.874934 U(25)=  .266849  M(25)=  .070033  MG(1)=   .079396
           .369746          .025181           .002560          -.026477 U(13)=  .232663 UP(13)=  .142193 MG(25)=  -.083259
STEP(  14) T=  .125826 P(1)=108.664515 P(13)=106.993038 P(25)=104.680029 U(25)=  .267030  M(25)=  .070031  MG(1)=   .074007
           .431309          .018415           .002746          -.018931 U(13)=  .237050 UP(13)=  .150160 MG(25)=  -.077484
STEP(  16) T=  .143780 P(1)=107.943873 P(13)=106.995406 P(25)=105.509198 U(25)=  .267232  M(25)=  .070030  MG(1)=   .064209
           .492853          .011656           .002769          -.011168 U(13)=  .238020 UP(13)=  .157322 MG(25)=  -.066839
STEP(  18) T=  .161741 P(1)=107.234506 P(13)=106.969132 P(25)=106.330896 U(25)=  .267425  M(25)=  .070029  MG(1)=   .050828
           .554422          .005609           .002522          -.003459 U(13)=  .236049 UP(13)=  .163373 MG(25)=  -.051955
STEP(  20) T=  .179722 P(1)=106.554451 P(13)=106.905305 P(25)=107.116138 U(25)=  .267609  M(25)=  .070029  MG(1)=   .034326
           .616055         -.001364           .001924           .003900 U(13)=  .231641 UP(13)=  .168101 MG(25)=  -.033639
STEP(  22) T=  .197717 P(1)=105.918762 P(13)=106.816591 P(25)=107.830335 U(25)=  .267778  M(25)=  .070029  MG(1)=   .015586
           .677739         -.007322           .001093           .010669 U(13)=  .224840 UP(13)=  .171699 MG(25)=  -.012053
STEP(  24) T=  .215728 P(1)=105.340655 P(13)=106.733929 P(25)=108.474975 U(25)=  .267927  M(25)=  .070030  MG(1)=  -.004537
           .739477         -.012740           .000318           .016635 U(13)=  .215297 UP(13)=  .173902 MG(25)=   .009354
STEP(  26) T=  .233735 P(1)=104.832614 P(13)=106.682766 P(25)=109.007153 U(25)=  .268052  M(25)=  .070031  MG(1)=  -.025135
           .801205         -.017501          -.000162           .021623 U(13)=  .202892 UP(13)=  .174797 MG(25)=   .031068
STEP(  28) T=  .251735 P(1)=104.405526 P(13)=106.668769 P(25)=109.421139 U(25)=  .268149  M(25)=  .070033  MG(1)=  -.045325
           .862906         -.021504          -.000293           .025503 U(13)=  .188025 UP(13)=  .174489 MG(25)=   .053683
STEP(  30) T=  .269730 P(1)=104.068513 P(13)=106.684589 P(25)=109.707649 U(25)=  .268216  M(25)=  .070034  MG(1)=  -.064263
           .924587         -.024662          -.000141           .028188 U(13)=  .171368 UP(13)=  .173240 MG(25)=   .073541
STEP(  32) T=  .287728 P(1)=103.825979 P(13)=106.723303 P(25)=109.861546 U(25)=  .268252  M(25)=  .070035  MG(1)=  -.081103
           .986256         -.026936           .000218           .029630 U(13)=  .153606 UP(13)=  .171319 MG(25)=   .090763
STEP(  34) T=  .305709 P(1)=103.673214 P(13)=106.776274 P(25)=109.882257 U(25)=  .268257  M(25)=  .070036  MG(1)=  -.095447
          1.047910         -.028367           .000715           .029824 U(13)=  .135645 UP(13)=  .168328 MG(25)=   .104404
STEP(  36) T=  .323658 P(1)=103.599461 P(13)=106.836143 P(25)=109.773627 U(25)=  .268232  M(25)=  .070037  MG(1)=  -.106589
          1.109582         -.029058           .001276           .028806 U(13)=  .118244 UP(13)=  .164078 MG(25)=   .114077
STEP(  38) T=  .341650 P(1)=103.602208 P(13)=106.894616 P(25)=109.542693 U(25)=  .268177  M(25)=  .070038  MG(1)=  -.114269
          1.171253         -.029033           .001824           .026642 U(13)=  .102038 UP(13)=  .158505 MG(25)=   .119090
STEP(  40) T=  .359605 P(1)=103.700814 P(13)=106.944901 P(25)=109.206122 U(25)=  .268099  M(25)=  .070038  MG(1)=  -.118150
          1.232930         -.028109           .002295           .023488 U(13)=  .087519 UP(13)=  .152026 MG(25)=   .119317
STEP(  42) T=  .377686 P(1)=103.926499 P(13)=106.982657 P(25)=108.792208 U(25)=  .268001  M(25)=  .070038  MG(1)=  -.117091
          1.294641         -.025993           .002649           .019608 U(13)=  .075047 UP(13)=  .144690 MG(25)=   .114775
STEP(  44) T=  .395693 P(1)=104.294102 P(13)=107.005642 P(25)=108.323366 U(25)=  .267892  M(25)=  .070038  MG(1)=  -.113152
          1.356366         -.022547           .002864           .015214 U(13)=  .064875 UP(13)=  .136915 MG(25)=   .105720
STEP(  46) T=  .413706 P(1)=104.707260 P(13)=107.012912 P(25)=107.816391 U(25)=  .267773  M(25)=  .070038  MG(1)=  -.103047
          1.418114         -.017926           .002933           .010463 U(13)=  .057174 UP(13)=  .129054 MG(25)=   .092590
STEP(  48) T=  .431720 P(1)=105.369405 P(13)=107.003690 P(25)=107.286299 U(25)=  .267649  M(25)=  .070038  MG(1)=  -.090104
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                1.479888          -.012470            .002846             .005495  U(13)=   .052029  UP(13)=   .121436  MG(25)=   .075911
STEP(  50)  T=   .449756  P(1)=106.004409  P(13)=106.976275  P(25)=106.746421  U(25)=   .267522   M(25)=   .078038   MG(1)=  -.072628
                1.541686          -.006519            .002589             .000435  U(13)=   .049421  UP(13)=   .114344  MG(25)=   .056341
STEP(  52)  T=   .467790  P(1)=106.663168  P(13)=106.928675  P(25)=106.208638  U(25)=   .267396   M(25)=   .078038   MG(1)=  -.051829
                1.603505          -.000345            .002143            -.004605  U(13)=   .049258  UP(13)=   .107996  MG(25)=   .034603
STEP(  54)  T=   .485828  P(1)=107.319597  P(13)=106.862645  P(25)=105.684187  U(25)=   .267273   M(25)=   .078038   MG(1)=  -.028575
                1.665333           .005811            .001524            -.009520  U(13)=   .051461  UP(13)=   .102545  MG(25)=   .011472
STEP(  56)  T=   .503858  P(1)=107.950122  P(13)=106.788401  P(25)=105.184346  U(25)=   .267156   M(25)=   .078038   MG(1)=  -.003768
                1.727139           .011716            .000829            -.014205  U(13)=   .056046  UP(13)=   .098087  MG(25)=  -.012249
STEP(  58)  T=   .521880  P(1)=108.531728  P(13)=106.724174  P(25)=104.720203  U(25)=   .267047   M(25)=   .078038   MG(1)=   .021638
                1.788916           .017167            .000227            -.018555  U(13)=   .063092  UP(13)=   .094672  MG(25)=  -.035767
STEP(  60)  T=   .539895  P(1)=109.047020  P(13)=106.687905  P(25)=104.302759  U(25)=   .266949   M(25)=   .078038   MG(1)=   .046680
                1.850667           .021996           -.000113            -.022467  U(13)=   .072586  UP(13)=   .092294  MG(25)=  -.058316
STEP(  62)  T=   .557903  P(1)=109.481680  P(13)=106.687389  P(25)=103.941628  U(25)=   .266864   M(25)=   .078037   MG(1)=   .070420
                1.912396           .026070           -.000118            -.025852  U(13)=   .084289  UP(13)=   .090857  MG(25)=  -.079172
STEP(  64)  T=   .575906  P(1)=109.824109  P(13)=106.718057  P(25)=103.644079  U(25)=   .266795   M(25)=   .078037   MG(1)=   .091981
                1.974106           .029279            .000169            -.028640  U(13)=   .097772  UP(13)=   .090106  MG(25)=  -.097687
STEP(  66)  T=   .593905  P(1)=110.065177  P(13)=106.769378  P(25)=103.414453  U(25)=   .266741   M(25)=   .078036   MG(1)=   .110569
                2.035803           .031539            .000650            -.030792  U(13)=   .112333  UP(13)=   .090119  MG(25)=  -.113306
STEP(  68)  T=   .611901  P(1)=110.198398  P(13)=106.831134  P(25)=103.254713  U(25)=   .266703   M(25)=   .078036   MG(1)=   .125500
                2.097492           .032787            .001229            -.032289  U(13)=   .127177  UP(13)=   .091235  MG(25)=  -.125586
STEP(  70)  T=   .629896  P(1)=110.221992  P(13)=106.896107  P(25)=103.170313  U(25)=   .266684   M(25)=   .078035   MG(1)=   .136228
                2.159176           .033008            .001838            -.033080  U(13)=   .141675  UP(13)=   .093590  MG(25)=  -.134181

NPMAX =   2     TMAX =    1.1404     PMAX =   -.02914     PK-PK AMPLITUDE =    .07914 AT T =     .5702     PMEAN =    .01043
STEP(  72)  T=   .647892  P(1)=110.140797  P(13)=106.959133  P(25)=103.174622  U(25)=   .266685   M(25)=   .078034   MG(1)=   .142376
                2.220862           .032247            .002429            -.033040  U(13)=   .155304  UP(13)=   .097156  MG(25)=  -.138802
STEP(  74)  T=   .665889  P(1)=109.966013  P(13)=107.015266  P(25)=103.286343  U(25)=   .266711   M(25)=   .078032   MG(1)=   .143764
                2.282554           .030609            .002955            -.031993  U(13)=   .167651  UP(13)=   .101775  MG(25)=  -.139191
STEP(  76)  T=   .683890  P(1)=109.713326  P(13)=107.059503  P(25)=103.518749  U(25)=   .266765   M(25)=   .078031   MG(1)=   .140415
                2.344255           .028241            .003369            -.029815  U(13)=   .178441  UP(13)=   .107203  MG(25)=  -.135148
STEP(  78)  T=   .701893  P(1)=109.399425  P(13)=107.088023  P(25)=103.867951  U(25)=   .266847   M(25)=   .078029   MG(1)=   .132546
                2.405969           .025299            .003637            -.026542  U(13)=   .187494  UP(13)=   .113154  MG(25)=  -.126619
STEP(  80)  T=   .719902  P(1)=109.038972  P(13)=107.098808  P(25)=104.311796  U(25)=   .266951   M(25)=   .078028   MG(1)=   .120530
                2.467699           .021921            .003738            -.022382  U(13)=   .194674  UP(13)=   .119333  MG(25)=  -.113773
STEP(  82)  T=   .737915  P(1)=108.643792  P(13)=107.090978  P(25)=104.819750  U(25)=   .267070   M(25)=   .078027   MG(1)=   .104865
                2.529446           .018217            .003664            -.017622  U(13)=   .198876  UP(13)=   .125458  MG(25)=  -.097016
STEP(  84)  T=   .755934  P(1)=108.223990  P(13)=107.064304  P(25)=105.363518  U(25)=   .267198   M(25)=   .078026   MG(1)=   .086142
                2.591210           .014283            .003414            -.012526  U(13)=   .203029  UP(13)=   .131275  MG(25)=  -.076943
STEP(  86)  T=   .773958  P(1)=107.789460  P(13)=107.020208  P(25)=105.[illegible]19921  U(25)=   .267328   M(25)=   .078025   MG(1)=   .065023
                2.652994           .010210            .003001            -.007311  U(13)=   .204104  UP(13)=   .136565  MG(25)=  -.054283
STEP(  88)  T=   .791988  P(1)=107.350544  P(13)=106.963735  P(25)=106.468703  U(25)=   .267457   M(25)=   .078025   MG(1)=   .042222
                2.714798           .006097            .002472            -.002168  U(13)=   .203094  UP(13)=   .141156  MG(25)=  -.029853
STEP(  90)  T=   .810023  P(1)=106.917477  P(13)=106.904566  P(25)=106.991045  U(25)=   .267579   M(25)=   .078025   MG(1)=   .018483
                2.776619           .002038            .001917             .002728  U(13)=   .199992  UP(13)=   .144915  MG(25)=  -.004529
STEP(  92)  T=   .828053  P(1)=106.499514  P(13)=106.855406  P(25)=107.470068  U(25)=   .267692   M(25)=   .078025   MG(1)=  -.005436
                2.838422          -.001879            .001456             .007217  U(13)=   .194802  UP(13)=   .147753  MG(25)=   .020776
STEP(  94)  T=   .846076  P(1)=106.104344  P(13)=105.827682  P(25)=107.891857  U(25)=   .267790   M(25)=   .078026   MG(1)=  -.028814
                2.900202          -.005583            .001197             .011170  U(13)=   .187587  UP(13)=   .149627  MG(25)=   .045176
STEP(  96)  T=   .864092  P(1)=105.739152  P(13)=106.827046  P(25)=108.244868  U(25)=   .267873   M(25)=   .078026   MG(1)=  -.050981
                2.961959          -.009005            .001191             .014479  U(13)=   .178529  UP(13)=   .150546  MG(25)=   .067836
STEP(  98)  T=   .882104  P(1)=105.411468  P(13)=106.851664  P(25)=108.519408  U(25)=   .267938   M(25)=   .078027   MG(1)=  -.071319
                3.023700          -.012076            .001421             .017052  U(13)=   .167949  UP(13)=   .150579  MG(25)=   .087992
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LINEAR COMB. RESP., 20.0 MICRON FARTICLES, 0.05 AMPL.

COMPUTATICN STEP(100) WHERE TIME(NON-DIMENSIONAL)= .9001E+00 DT= .9003E-02 T(MIL-SEC)= .1440E+01

REGION(1) WHERE SMB= -.10000E+01 SMC= 0. CMB= .10000E+01

INDEX M	X STR	MACH NO.	PRESSURE	DENSITY	VELOCITY	ENTROPY	ENTHALPY	A(LOC)
1	-.195800E+01	0.	.105129E+03	.897474E+01	0.	.195606E+01	.117139E+02	.342256E+01
2	-.187642E+01	.435964E-02	.105140E+03	.897547E+01	.149213E-01	.195606E+01	.117141E+02	.342259E+01
3	-.179483E+01	.863324E-02	.105174E+03	.897776E+01	.297544E-01	.195607E+01	.117149E+02	.342271E+01
4	-.171325E+01	.129834E-01	.105231E+03	.898160E+01	.444411E-01	.195609E+01	.117163E+02	.342291E+01
5	-.163167E+01	.172050E-01	.105312E+03	.898705E+01	.588960E-01	.195612E+01	.117182E+02	.342319E+01
6	-.155008E+01	.213263E-01	.105419E+03	.899421E+01	.730117E-01	.195615E+01	.117208E+02	.342356E+01
7	-.146850E+01	.253179E-01	.105553E+03	.900321E+01	.866890E-01	.195619E+01	.117239E+02	.342402E+01
8	-.138692E+01	.291509E-01	.105715E+03	.901412E+01	.998294E-01	.195623E+01	.117277E+02	.342457E+01
9	-.130533E+01	.328015E-01	.105905E+03	.902698E+01	.112352E+00	.195628E+01	.117321E+02	.342521E+01
10	-.122375E+01	.362605E-01	.106123E+03	.904171E+01	.124226E+00	.195633E+01	.117371E+02	.342594E+01
11	-.114217E+01	.395293E-01	.106364E+03	.905805E+01	.135456E+00	.195638E+01	.117425E+02	.342674E+01
12	-.106058E+01	.426264E-01	.106624E+03	.907564E+01	.146106E+00	.195643E+01	.117484E+02	.342759E+01
13	-.979000E+00	.455787E-01	.106894E+03	.909400E+01	.156265E+00	.195647E+01	.117544E+02	.342847E+01
14	-.897417E+00	.484159E-01	.107169E+03	.911265E+01	.166035E+00	.195652E+01	.117605E+02	.342935E+01
15	-.815833E+00	.511676E-01	.107440E+03	.913110E+01	.175516E+00	.195656E+01	.117664E+02	.343022E+01
16	-.734250E+00	.538575E-01	.107702E+03	.914890E+01	.184788E+00	.195660E+01	.117722E+02	.343106E+01
17	-.652667E+00	.565067E-01	.107949E+03	.916565E+01	.193922E+00	.195664E+01	.117775E+02	.343184E+01
18	-.571083E+00	.591358E-01	.108174E+03	.918092E+01	.202987E+00	.195667E+01	.117824E+02	.343256E+01
19	-.489500E+00	.617602E-01	.108371E+03	.919431E+01	.212034E+00	.195670E+01	.117867E+02	.343318E+01
20	-.407917E+00	.643943E-01	.108535E+03	.920544E+01	.221111E+00	.195673E+01	.117903E+02	.343371E+01
21	-.326333E+00	.670492E-01	.108661E+03	.921395E+01	.230255E+00	.195675E+01	.117931E+02	.343411E+01
22	-.244750E+00	.697306E-01	.108745E+03	.921954E+01	.239483E+00	.195678E+01	.117951E+02	.343440E+01
23	-.163167E+00	.724507E-01	.108783E+03	.922194E+01	.248836E+00	.195681E+01	.117962E+02	.343455E+01
24	-.815833E-01	.752132E-01	.108772E+03	.922090E+01	.258324E+00	.195684E+01	.117962E+02	.343456E+01
25	0.	.780282E-01	.108708E+03	.921626E+01	.267982E+00	.195687E+01	.117953E+02	.343442E+01

INCEX OF DISCONTINUITY CIRECTION= 0 ANC DISCONTINUITY LOCATION= 0.

INDEX M	X STR	PARTICLE DENSITY	PARTICLE VELOCITY	SMDG	SMDP	SMDDG
1	-.195800E+01	.401682E+01	0.	.560912E-01	.201928E-01	-.591854E-01
2	-.187642E+01	.399957E+01	.114673E-01	.562005E-01	.202322E-01	-.581725E-01
3	-.179483E+01	.397497E+01	.238562E-01	.563098E-01	.202715E-01	-.571596E-01
4	-.171325E+01	.396107E+01	.367418E-01	.565388E-01	.203540E-01	-.549431E-01
5	-.163167E+01	.395281E+01	.499082E-01	.568476E-01	.204651E-01	-.519241E-01
6	-.155008E+01	.394825E+01	.632014E-01	.571939E-01	.205898E-01	-.484828E-01
7	-.146850E+01	.394632E+01	.764646E-01	.576905E-01	.207686E-01	-.433522E-01
8	-.138692E+01	.394672E+01	.896347E-01	.581870E-01	.209473E-01	-.382216E-01
9	-.130533E+01	.394911E+01	.102542E+00	.588083E-01	.211710E-01	-.316291E-01
10	-.122375E+01	.395341E+01	.115102E+00	.594607E-01	.214059E-01	-.246711E-01
11	-.114217E+01	.395957E+01	.127223E+00	.601545E-01	.216556E-01	-.173110E-01
12	-.106058E+01	.396767E+01	.138831E+00	.609104E-01	.219277E-01	-.934771E-02
13	-.979000E+00	.397776E+01	.149861E+00	.616662E-01	.221998E-01	-.138439E-02
14	-.897417E+00	.398975E+01	.160272E+00	.624584E-01	.224850E-01	.652171E-02
15	-.815833E+00	.400364E+01	.170037E+00	.632505E-01	.227702E-01	.144278E-01
16	-.734250E+00	.401914E+01	.179149E+00	.640131E-01	.230447E-01	.217449E-01
17	-.652667E+00	.403732E+01	.187628E+00	.647559E-01	.233121E-01	.286692E-01
18	-.571083E+00	.405356E+01	.195498E+00	.654711E-01	.235696E-01	.352449E-01
19	-.489500E+00	.408237E+01	.202845E+00	.660764E-01	.237875E-01	.404259E-01
20	-.407917E+00	.408924E+01	.209666E+00	.666817E-01	.240054E-01	.456069E-01
21	-.326333E+00	.413501E+01	.216188E+00	.671152E-01	.241615E-01	.489979E-01
22	-.244750E+00	.414807E+01	.222338E+00	.675058E-01	.243021E-01	.519415E-01
23	-.163167E+00	.418650E+01	.228388E+00	.677927E-01	.244054E-01	.539423E-01
24	-.815833E-01	.423683E+01	.233846E+00	.679240E-01	.244527E-01	.545287E-01
25	0.	.427539E+01	.240440E+00	.680554E-01	.244999E-01	.551152E-01

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IBS        XSTRSS        F SMOG          R           TEMP SUR.      PRESS(LOC)
  1     -.195800E+01  .560312E-01  .134487E+01  .264191E+01  .105129E+03
  2     -.176220E+01  .563535E-01  .135115E+01  .264303E+01  .105137E+03
  3     -.156640E+01  .570946E-01  .136832E+01  .264643E+01  .105398E+03
  4     -.137060E+01  .582863E-01  .139750E+01  .265181E+01  .105753E+03
  5     -.117480E+01  .598522E-01  .143504E+01  .265888E+01  .106268E+03
  6     -.979000E+00  .616662E-01  .147853E+01  .266707E+01  .106894E+03
  7     -.783200E+00  .635674E-01  .152412E+01  .267565E+01  .107545E+03
  8     -.587400E+00  .653500E-01  .156686E+01  .268369E+01  .108129E+03
  9     -.391600E+00  .668027E-01  .160169E+01  .269025E+01  .108561E+03
 10     -.195900E+00  .677401E-01  .162416E+01  .269448E+01  .108768E+03
 11     0.            .680554E-01  .163172E+01  .269590E+01  .108708E+03
STEP( 100)  T=   .900112  P(1)=105.129085  P(13)=106.894398  P(25)=108.708172  U(25)=   .267982   M(25)=   .078028   MG(1)=  -.089281
                3.095427         -.014723           .001922           .018821  U(13)=   .156265  UP(13)=   .149861   MG(25)=   .104974
STEP( 102)  T=   .918117  P(1)=104.899950  P(13)=106.946880  P(25)=108.807344  U(25)=   .268005   M(25)=   .078029   MG(1)=  -.104387
                3.147146         -.016870           .002314           .019750  U(13)=   .143900  UP(13)=   .148613   MG(25)=   .118231
STEP( 104)  T=   .936121  P(1)=104.733098  P(13)=107.001852  P(25)=108.817436  U(25)=   .268007   M(25)=   .078030   MG(1)=  -.116234
                3.208861         -.018434           .002829           .019845  U(13)=   .131334  UP(13)=   .146881   MG(25)=   .127354
STEP( 106)  T=   .954125  P(1)=104.640221  P(13)=107.053012  P(25)=108.743117  U(25)=   .267990   M(25)=   .078031   MG(1)=  -.124479
                3.270576         -.019304           .003308           .019148  U(13)=   .119108  UP(13)=   .144473   MG(25)=   .132091
STEP( 108)  T=   .972131  P(1)=104.636046  P(13)=107.095687  P(25)=108.591886  U(25)=   .267955   M(25)=   .078031   MG(1)=  -.128831
                3.332296         -.019344           .003708           .017731  U(13)=   .107643  UP(13)=   .141345   MG(25)=   .132359

NPMAX =   3     TMAX =    2.1283      PMAX =    .03302      PK-PK AMPLITUDE =    .06217 AT T =    1.6344      PMEAN =    .00194
STEP( 110)  T=   .990139  P(1)=104.734744  P(13)=107.125953  P(25)=108.371971  U(25)=   .267903   M(25)=   .078031   MG(1)=  -.129055
                3.394026         -.018419           .003992           .015670  U(13)=   .097268  UP(13)=   .137551   MG(25)=   .128225
STEP( 112)  T=  1.008151  P(1)=104.942797  P(13)=107.140875  P(25)=108.093761  U(25)=   .267838   M(25)=   .078032   MG(1)=  -.125003
                3.455767         -.016469           .004132           .013062  U(13)=   .088235  UP(13)=   .133218   MG(25)=   .119910
STEP( 114)  T=  1.026167  P(1)=105.253566  P(13)=107.138992  P(25)=107.771942  U(25)=   .267762   M(25)=   .078032   MG(1)=  -.116679
                3.517522         -.013552           .004114           .010046  U(13)=   .080739  UP(13)=   .128521   MG(25)=   .107787
STEP( 116)  T=  1.044187  P(1)=105.649304  P(13)=107.120182  P(25)=107.418660  U(25)=   .267680   M(25)=   .078032   MG(1)=  -.104281
                3.579294         -.009847           .003938           .006735  U(13)=   .074930  UP(13)=   .123656   MG(25)=   .092350
STEP( 118)  T=  1.062213  P(1)=106.102741  P(13)=107.085706  P(25)=107.043072  U(25)=   .267591   M(25)=   .078032   MG(1)=  -.088215
                3.641083         -.005598           .003615           .003215  U(13)=   .073927  UP(13)=   .118823   MG(25)=   .074173
STEP( 120)  T=  1.080243  P(1)=106.588216  P(13)=107.038728  P(25)=106.654106  U(25)=   .267500   M(25)=   .078032   MG(1)=  -.069061
                3.702888         -.001048           .003175          -.000430  U(13)=   .068821  UP(13)=   .114212   MG(25)=   .053890
STEP( 122)  T=  1.098278  P(1)=107.083585  P(13)=106.985001  P(25)=106.260657  U(25)=   .267408   M(25)=   .078032   MG(1)=  -.047525
                3.764708          .003595           .002671          -.004118  U(13)=   .069584  UP(13)=   .109990   MG(25)=   .032177
STEP( 124)  T=  1.116314  P(1)=107.570520  P(13)=106.932457  P(25)=105.871124  U(25)=   .267317   M(25)=   .078032   MG(1)=  -.024393
                3.826530          .008159           .002182          -.007768  U(13)=   .070581  UP(13)=   .106298   MG(25)=   .009728
STEP( 126)  T=  1.134342  P(1)=108.033036  P(13)=106.891685  P(25)=105.493401  U(25)=   .267228   M(25)=   .078032   MG(1)=  -.000502
                3.888330          .012493           .001796          -.011308  U(13)=   .074557  UP(13)=   .103242   MG(25)=  -.012764
STEP( 128)  T=  1.152365  P(1)=108.457026  P(13)=106.869353  P(25)=105.135051  U(25)=   .267144   M(25)=   .078032   MG(1)=   .023313
                3.950109          .016467           .001587          -.014667  U(13)=   .080584  UP(13)=   .100881   MG(25)=  -.034640
STEP( 130)  T=  1.170383  P(1)=108.830115  P(13)=106.869975  P(25)=104.803974  U(25)=   .267067   M(25)=   .078032   MG(1)=   .046234
                4.011870          .019964           .001593          -.017770  U(13)=   .088510  UP(13)=   .099212   MG(25)=  -.055282
STEP( 132)  T=  1.188395  P(1)=109.141824  P(13)=106.892691  P(25)=104.508286  U(25)=   .266997   M(25)=   .078032   MG(1)=   .067491
                4.073615          .022885           .001806          -.020541  U(13)=   .098039  UP(13)=   .098150   MG(25)=  -.074119
STEP( 134)  T=  1.206405  P(1)=109.383638  P(13)=106.932102  P(25)=104.256624  U(25)=   .266938   M(25)=   .078031   MG(1)=   .086380
                4.135346          .025151           .002175          -.022899  U(13)=   .108785  UP(13)=   .097543   MG(25)=  -.090640
STEP( 136)  T=  1.224411  P(1)=109.549219  P(13)=106.980859  P(25)=104.059028  U(25)=   .266892   M(25)=   .078031   MG(1)=   .102292
                4.197069          .026703           .002632          -.024751  U(13)=   .120152  UP(13)=   .097625   MG(25)=  -.104391
STEP( 138)  T=  1.242415  P(1)=109.635358  P(13)=107.032193  P(25)=103.926803  U(25)=   .266861   M(25)=   .078030   MG(1)=   .114725
                4.258785          .027510           .003113          -.025991  U(13)=   .131599  UP(13)=   .098563   MG(25)=  -.114975
STEP( 140)  T=  1.260419  P(1)=109.642809  P(13)=107.081744  P(25)=103.872636  U(25)=   .266848   M(25)=   .078030   MG(1)=   .123314
                4.320500          .027580           .003578          -.026498  U(13)=   .142673  UP(13)=   .100410   MG(25)=  -.122051

NPMAX =   4     TMAX =    3.3014      PMAX =   -.01944      PK-PK AMPLITUDE =    .05246 AT T =    2.7149      PMEAN =    .00679
STEP( 142)  T=  1.278424  P(1)=109.575851  P(13)=107.125978  P(25)=103.908280  U(25)=   .266857   M(25)=   .078029   MG(1)=   .127838
                4.382216          .026953           .003992          -.026164  U(13)=   .153031  UP(13)=   .103119   MG(25)=  -.125342
STEP( 144)  T=  1.296430  P(1)=109.441392  P(13)=107.160758  P(25)=104.040597  U(25)=   .266888   M(25)=   .078028   MG(1)=   .128231
                4.443937          .025893           .004318          -.024924  U(13)=   .162436  UP(13)=   .106570   MG(25)=  -.124653
STEP( 146)  T=  1.314438  P(1)=109.248212  P(13)=107.182400  P(25)=104.267384  U(25)=   .266941   M(25)=   .078027   MG(1)=   .124576
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              4.505665          .023982              .004521              -.022799  U(13)=    .170714  UP(13)=   .110599  MG(25)=  -.115919
STEP( 148)  T= 1.332448  P(1)=109.066251  P(13)=107.189321  P(25)=104.576210  U(25)=    .267013   M(25)=   .078026   MG(1)=   .117092
              4.567403          .021614              .004582              -.019904  U(13)=    .177712  UP(13)=   .115013  MG(25)=  -.111238
STEP( 150)  T= 1.350462  P(1)=108.725599  P(13)=107.180059  P(25)=104.947170  U(25)=    .267100   M(25)=   .078025   MG(1)=   .106127
              4.629152          .018984              .004499              -.016428  U(13)=    .183292  UP(13)=   .119609  MG(25)=  -.098891
STEP( 152)  T= 1.368480  P(1)=108.415621  P(13)=107.157010  P(25)=105.358208  U(25)=    .267197   M(25)=   .078024   MG(1)=   .092124
              4.690915          .016079              .004283              -.012575  U(13)=    .187335  UP(13)=   .124189  MG(25)=  -.083328
STEP( 154)  T= 1.386503  P(1)=108.084938  P(13)=107.122645  P(25)=105.789327  U(25)=    .267298   M(25)=   .078023   MG(1)=   .075607
              4.752692          .012980              .003961              -.008535  U(13)=    .189736  UP(13)=   .128563  MG(25)=  -.065129
STEP( 156)  T= 1.404529  P(1)=107.741958  P(13)=107.081868  P(25)=106.223835  U(25)=    .267399   M(25)=   .078023   MG(1)=   .057155
              4.814484          .009765              .003579              -.004463  U(13)=    .190411  UP(13)=   .132561  MG(25)=  -.044963
STEP( 158)  T= 1.422560  P(1)=107.394688  P(13)=107.041387  P(25)=106.647421  U(25)=    .267499   M(25)=   .078023   MG(1)=   .037384
              4.876292          .006511              .003200              -.000493  U(13)=    .189299  UP(13)=   .136039  MG(25)=  -.023555
STEP( 160)  T= 1.440594  P(1)=107.049945  P(13)=107.008586  P(25)=107.047203  U(25)=    .267592   M(25)=   .078023   MG(1)=   .016924
              4.938109          .003280              .002892               .003254  U(13)=    .186376  UP(13)=   .138879  MG(25)=  -.001658
STEP( 162)  T= 1.458624  P(1)=106.713459  P(13)=106.989820  P(25)=107.411337  U(25)=    .267678   M(25)=   .078024   MG(1)=  -.003601
              4.999910          .000126              .002716               .006667  U(13)=    .181688  UP(13)=   .141000  MG(25)=   .019969
STEP( 164)  T= 1.476647  P(1)=106.390892  P(13)=106.988661  P(25)=107.729613  U(25)=    .267752   M(25)=   .078024   MG(1)=  -.023605
              5.061692         -.002897              .002705               .009650  U(13)=    .175374  UP(13)=   .142362  MG(25)=   .040596
STEP( 166)  T= 1.494666  P(1)=106.089109  P(13)=107.004939  P(25)=107.993433  U(25)=    .267814   M(25)=   .078025   MG(1)=  -.042534
              5.123458         -.005725              .002858               .012122  U(13)=    .167671  UP(13)=   .142976  MG(25)=   .059550
STEP( 168)  T= 1.512682  P(1)=105.816400  P(13)=107.035078  P(25)=108.196046  U(25)=    .267862   M(25)=   .078025   MG(1)=  -.059876
              5.185211         -.008281              .003140               .014021  U(13)=    .153894  UP(13)=   .142896  MG(25)=   .076222
STEP( 170)  T= 1.530694  P(1)=105.582222  P(13)=107.073677  P(25)=108.332933  U(25)=    .267894   M(25)=   .078026   MG(1)=  -.075159
              5.246955         -.010476              .003502               .015304  U(13)=    .143385  UP(13)=   .142226  MG(25)=   .090095
STEP( 172)  T= 1.548705  P(1)=105.397128  P(13)=107.115304  P(25)=108.402158  U(25)=    .267910   M(25)=   .078027   MG(1)=  -.087959
              5.308693         -.012211              .003892               .015953  U(13)=    .133471  UP(13)=   .141113  MG(25)=   .100757
STEP( 174)  T= 1.566715  P(1)=105.272654  P(13)=107.155297  P(25)=108.404356  U(25)=    .267911   M(25)=   .078028   MG(1)=  -.097899
              5.370427         -.013377              .004267               .015973  U(13)=    .123467  UP(13)=   .139670  MG(25)=   .107916
STEP( 176)  T= 1.584725  P(1)=105.220568  P(13)=107.189567  P(25)=108.342322  U(25)=    .267896   M(25)=   .078028   MG(1)=  -.104650
              5.432163         -.013865              .004588               .015392  U(13)=    .113756  UP(13)=   .137770  MG(25)=   .111405

NPMAX =   5    TMAX =    4.2896    PMAX =    .02764     PK-PK AMPLITUDE =    .04707 AT T =    3.7955    PMEAN =    .00410
STEP( 178)  T= 1.602736  P(1)=105.251155  P(13)=107.214673  P(25)=108.220556  U(25)=    .267867   M(25)=   .078029   MG(1)=  -.107946
              5.493903         -.013579              .004824               .014251  U(13)=    .110641  UP(13)=   .135371  MG(25)=   .111184
STEP( 180)  T= 1.620750  P(1)=105.369584  P(13)=107.227860  P(25)=108.044580  U(25)=    .267826   M(25)=   .078029   MG(1)=  -.107604
              5.555650         -.012465              .004947               .012602  U(13)=    .102365  UP(13)=   .132500  MG(25)=   .107333
STEP( 182)  T= 1.638766  P(1)=105.574404  P(13)=107.227666  P(25)=107.820429  U(25)=    .267774   M(25)=   .078029   MG(1)=  -.103558
              5.617407         -.010543              .004945               .010501  U(13)=    .095139  UP(13)=   .129239  MG(25)=   .100047
STEP( 184)  T= 1.656786  P(1)=105.853181  P(13)=107.214139  P(25)=107.556527  U(25)=    .267712   M(25)=   .078030   MG(1)=  -.095896
              5.679175         -.007936              .004819               .008027  U(13)=    .089142  UP(13)=   .125702  MG(25)=   .089625
STEP( 186)  T= 1.674809  P(1)=106.188933  P(13)=107.188856  P(25)=107.264490  U(25)=    .267643   M(25)=   .078030   MG(1)=  -.084866
              5.740957         -.004790              .004582               .005290  U(13)=    .084531  UP(13)=   .122029  MG(25)=   .076474
STEP( 188)  T= 1.692837  P(1)=106.562117  P(13)=107.154907  P(25)=106.954050  U(25)=    .267571   M(25)=   .078030   MG(1)=  -.070872
              5.802752         -.001292              .004263               .002381  U(13)=    .081436  UP(13)=   .118366  MG(25)=   .061084
STEP( 190)  T= 1.710868  P(1)=106.954477  P(13)=107.116810  P(25)=106.632724  U(25)=    .267495   M(25)=   .078030   MG(1)=  -.054436
              5.864561          .002385              .003906              -.000631  U(13)=    .079967  UP(13)=   .114859  MG(25)=   .043988
STEP( 192)  T= 1.728903  P(1)=107.350429  P(13)=107.080250  P(25)=106.307205  U(25)=    .267419   M(25)=   .078030   MG(1)=  -.036167
              5.926382          .006096              .003564              -.003681  U(13)=    .080211  UP(13)=   .111639  MG(25)=   .025750
STEP( 194)  T= 1.746937  P(1)=107.736528  P(13)=107.051261  P(25)=105.983930  U(25)=    .267343   M(25)=   .078030   MG(1)=  -.016733
              5.988198          .009714              .003292              -.006711  U(13)=    .082216  UP(13)=   .108822  MG(25)=   .006945
STEP( 196)  T= 1.764965  P(1)=108.100803  P(13)=107.034809  P(25)=105.669210  U(25)=    .267269   M(25)=   .078030   MG(1)=   .003178
              6.049995          .013128              .003138              -.009661  U(13)=    .085981  UP(13)=   .106487  MG(25)=  -.011860
STEP( 198)  T= 1.782989  P(1)=108.432510  P(13)=107.033393  P(25)=105.369878  U(25)=    .267199   M(25)=   .078030   MG(1)=   .022876
              6.111777          .016237              .003125              -.012466  U(13)=    .091418  UP(13)=   .104674  MG(25)=  -.030121
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LINEAR COMB. RESP., 20.0 MICRON PARTICLES, 0.05 AMPL.

COMPUTATION STEP(200) WHERE TIME(NON-DIMENSIONAL)= .1801E+01 DT= .9003E-02 T(MIL-SEC)= .2882E+01

REGION(1) WHERE SMB= -.10000E+01 SMC= 0. CMB= .10000E+01

INDEX M	X STR	MACH NO.	PRESSURE	DENSITY	VELOCITY	ENTROPY	ENTHALPY	A(LOC)
1	-.195300E+01	0.	.108722E+03	.922418E+01	0.	.195595E+01	.117867E+02	.343317E+01
2	-.187642E+01	.197462E-02	.108709E+03	.922323E+01	.677914E-02	.195595E+01	.117864E+02	.343313E+01
3	-.179483E+01	.397270E-02	.108666E+03	.922024E+01	.136383E-01	.195596E+01	.117856E+02	.343302E+01
4	-.171325E+01	.600532E-02	.108596E+03	.921531E+01	.206153E-01	.195597E+01	.117843E+02	.343283E+01
5	-.163167E+01	.809365E-02	.108500E+03	.920850E+01	.277718E-01	.195599E+01	.117826E+02	.343258E+01
6	-.155008E+01	.102470E-01	.108379E+03	.919994E+01	.351703E-01	.195602E+01	.117804E+02	.343225E+01
7	-.146850E+01	.124907E-01	.108234E+03	.918974E+01	.428663E-01	.195605E+01	.117777E+02	.343187E+01
8	-.138692E+01	.148377E-01	.108069E+03	.917810E+01	.509144E-01	.195608E+01	.117747E+02	.343143E+01
9	-.130533E+01	.173043E-01	.107887E+03	.916520E+01	.593700E-01	.195612E+01	.117713E+02	.343094E+01
10	-.122375E+01	.199059E-01	.107689E+03	.915127E+01	.682854E-01	.195616E+01	.117677E+02	.343041E+01
11	-.114217E+01	.226594E-01	.107481E+03	.913655E+01	.777183E-01	.195620E+01	.117638E+02	.342984E+01
12	-.106058E+01	.255804E-01	.107265E+03	.912133E+01	.877218E-01	.195625E+01	.117598E+02	.342926E+01
13	-.979000E+00	.286826E-01	.107046E+03	.910590E+01	.983431E-01	.195629E+01	.117557E+02	.342866E+01
14	-.897417E+00	.319755E-01	.106829E+03	.909054E+01	.109614E+00	.195633E+01	.117517E+02	.342807E+01
15	-.815833E+00	.354616E-01	.106616E+03	.907553E+01	.121545E+00	.195637E+01	.117477E+02	.342749E+01
16	-.734250E+00	.391380E-01	.106412E+03	.906110E+01	.134123E+00	.195641E+01	.117438E+02	.342693E+01
17	-.652667E+00	.429942E-01	.106218E+03	.904741E+01	.147315E+00	.195645E+01	.117402E+02	.342640E+01
18	-.571083E+00	.470145E-01	.106037E+03	.903457E+01	.161067E+00	.195649E+01	.117368E+02	.342590E+01
19	-.489500E+00	.511747E-01	.105869E+03	.902265E+01	.175296E+00	.195653E+01	.117337E+02	.342545E+01
20	-.407917E+00	.554575E-01	.105714E+03	.901162E+01	.189944E+00	.195657E+01	.117309E+02	.342504E+01
21	-.326333E+00	.598464E-01	.105571E+03	.900136E+01	.204954E+00	.195661E+01	.117283E+02	.342466E+01
22	-.244750E+00	.643222E-01	.105437E+03	.899177E+01	.220260E+00	.195665E+01	.117259E+02	.342432E+01
23	-.163167E+00	.688604E-01	.105313E+03	.898280E+01	.235778E+00	.195670E+01	.117238E+02	.342400E+01
24	-.815833E-01	.734381E-01	.105198E+03	.897448E+01	.251432E+00	.195675E+01	.117219E+02	.342373E+01
25	0.	.780299E-01	.105094E+03	.896684E+01	.267135E+00	.195681E+01	.117203E+02	.342349E+01

INDEX OF DISCONTINUITY DIRECTION= 0 AND DISCONTINUITY LOCATION= 0.

INDEX M	X STR	PARTICLE DENSITY	PARTICLE VELOCITY	SMDG	SMDP	SMDDG
1	-.195800E+01	.396788E+01	0.	.641582E-01	.230969E-01	.633126E-01
2	-.187642E+01	.394621E+01	.802125E-02	.641037E-01	.230773E-01	.619834E-01
3	-.179483E+01	.391035E+01	.160219E-01	.640492E-01	.230577E-01	.606543E-01
4	-.171325E+01	.388817E+01	.239731E-01	.639378E-01	.230176E-01	.578576E-01
5	-.163167E+01	.387360E+01	.319309E-01	.637896E-01	.229639E-01	.540827E-01
6	-.155008E+01	.386401E+01	.399598E-01	.636232E-01	.229044E-01	.498651E-01
7	-.146850E+01	.385755E+01	.481362E-01	.633934E-01	.228216E-01	.438766E-01
8	-.138692E+01	.385356E+01	.565299E-01	.631635E-01	.227389E-01	.378882E-01
9	-.130533E+01	.385170E+01	.651970E-01	.628866E-01	.226392E-01	.306235E-01
10	-.122375E+01	.385181E+01	.741918E-01	.625980E-01	.225353E-01	.230398E-01
11	-.114217E+01	.385398E+01	.835449E-01	.622961E-01	.224266E-01	.151662E-01
12	-.106058E+01	.385810E+01	.932702E-01	.619745E-01	.223108E-01	.685798E-02
13	-.979000E+00	.386467E+01	.103369E+00	.616528E-01	.221950E-01	-.145027E-02
14	-.897417E+00	.387196E+01	.113817E+00	.613225E-01	.220761E-01	-.947031E-02
15	-.815833E+00	.388582E+01	.124581E+00	.609922E-01	.219572E-01	-.174904E-01
16	-.734250E+00	.389260E+01	.135578E+00	.606719E-01	.218419E-01	-.247919E-01
17	-.652667E+00	.391935E+01	.146769E+00	.603582E-01	.217289E-01	-.316145E-01
18	-.571083E+00	.392748E+01	.157959E+00	.600530E-01	.216191E-01	-.380637E-01
19	-.489500E+00	.395454E+01	.169135E+00	.597820E-01	.215215E-01	-.430195E-01
20	-.407917E+00	.399990E+01	.180128E+00	.595109E-01	.214239E-01	-.479752E-01
21	-.326333E+00	.400008E+01	.190653E+00	.592933E-01	.213456E-01	-.512700E-01
22	-.244750E+00	.403541E+01	.201328E+00	.590891E-01	.212721E-01	-.541496E-01
23	-.163167E+00	.406011E+01	.212643E+00	.589181E-01	.212105E-01	-.561757E-01
24	-.815833E-01	.408557E+01	.224819E+00	.587968E-01	.211669E-01	-.569216E-01
25	0.	.408163E+01	.236308E+00	.586756E-01	.211232E-01	-.576674E-01

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    IBS       XSTRES        F SMOG        R            TEMP SUR.     PRESS(LOC)
      1    -.195800E+01  .641582E-01  .153828E+01  .267831E+01  .108722E+03
      2    -.176220E+01  .640273E-01  .153514E+01  .267772E+01  .108638E+03
      3    -.156640E+01  .636692E-01  .152656E+01  .267611E+01  .108403E+03
      4    -.137080E+01  .631176E-01  .151333E+01  .267362E+01  .108033E+03
      5    -.117480E+01  .624248E-01  .149672E+01  .267043E+01  .107564E+03
      6    -.979000E+00  .616528E-01  .147821E+01  .266701E+01  .107046E+03
      7    -.783200E+00  .608601E-01  .145921E+01  .266343E+01  .106535E+03
      8    -.587400E+00  .601072E-01  .144115E+01  .266003E+01  .106073E+03
      9    -.391600E+00  .594567E-01  .142556E+01  .265709E+01  .105686E+03
     10    -.195800E+00  .589666E-01  .141381E+01  .265488E+01  .105362E+03
     11    0.            .586756E-01  .140683E+01  .265357E+01  .105094E+03
STEP( 200)  T=  1.801008  P(1)=108.722196  P(13)=107.046496  P(25)=105.093918  U(25)=   .267135   M(25)=   .078030   MG(1)=    .041698
                6.173544          .018952           .003247          -.015052  U(13)=   .093343  UP(13)=   .103369  MG(25)=  -.047320
STEP( 202)  T=  1.819024  P(1)=108.961933  P(13)=107.071189  P(25)=104.850487  U(25)=   .267078   M(25)=   .078030   MG(1)=    .059021
                6.235299          .021199           .003479          -.017334  U(13)=   .106489  UP(13)=   .102475  MG(25)=  -.062970
STEP( 204)  T=  1.837036  P(1)=109.145471  P(13)=107.103519  P(25)=104.649273  U(25)=   .267030   M(25)=   .078029   MG(1)=    .074285
                6.297044          .022919           .003782          -.019220  U(13)=   .115471  UP(13)=   .102000  MG(25)=  -.076621
STEP( 206)  T=  1.855047  P(1)=109.268409  P(13)=107.139854  P(25)=104.500706  U(25)=   .266996   M(25)=   .078029   MG(1)=    .087013
                6.358782          .024071           .004122          -.020612  U(13)=   .124812  UP(13)=   .102129  MG(25)=  -.087869
STEP( 208)  T=  1.873057  P(1)=109.328733  P(13)=107.177033  P(25)=104.415337  U(25)=   .266976   M(25)=   .078029   MG(1)=    .096819
                6.420516          .024637           .004471          -.021412  U(13)=   .134105  UP(13)=   .102954  MG(25)=  -.096354
STEP( 210)  T=  1.891066  P(1)=109.326962  P(13)=107.211917  P(25)=104.402254  U(25)=   .266972   M(25)=   .078028   MG(1)=    .103429
                6.482248          .024620           .004798          -.021535  U(13)=   .143034  UP(13)=   .104487  MG(25)=  -.101776

NPMAX =    6    TMAX =    5.4322     PMAX =  -.01387     PK-PK AMPLITUDE =    .04150 AT T =    4.8609      PMEAN =    .00689
STEP( 212)  T=  1.909076  P(1)=109.265797  P(13)=107.240709  P(25)=104.467084  U(25)=   .266988   M(25)=   .078027   MG(1)=    .106684
                6.543982          .024047           .005068          -.020927  U(13)=   .151380  UP(13)=   .106682  MG(25)=  -.103910
STEP( 214)  T=  1.927087  P(1)=109.149693  P(13)=107.260077  P(25)=104.609720  U(25)=   .267021   M(25)=   .078027   MG(1)=    .106543
                6.605720          .022959           .005249          -.019590  U(13)=   .158970  UP(13)=   .109442  MG(25)=  -.102637
STEP( 216)  T=  1.945059  P(1)=108.984637  P(13)=107.268211  P(25)=104.823078  U(25)=   .267071   M(25)=   .078026   MG(1)=    .103080
                6.667465          .021412           .005325          -.017591  U(13)=   .165643  UP(13)=   .112643  MG(25)=  -.097961
STEP( 218)  T=  1.963114  P(1)=108.778066  P(13)=107.264879  P(25)=105.094273  U(25)=   .267135   M(25)=   .078025   MG(1)=    .096484
                6.729217          .019476           .005294          -.015049  U(13)=   .171251  UP(13)=   .116138  MG(25)=  -.090035
STEP( 220)  T=  1.981132  P(1)=108.538545  P(13)=107.251138  P(25)=105.407430  U(25)=   .267208   M(25)=   .078025   MG(1)=    .087040
                6.790979          .017231           .005165          -.012114  U(13)=   .175659  UP(13)=   .119769  MG(25)=  -.079151
STEP( 222)  T=  1.999154  P(1)=108.275050  P(13)=107.229194  P(25)=105.746766  U(25)=   .267288   M(25)=   .078024   MG(1)=    .075128
                6.852753          .014761           .004960          -.008934  U(13)=   .178750  UP(13)=   .123379  MG(25)=  -.065721
STEP( 224)  T=  2.017178  P(1)=107.996094  P(13)=107.202398  P(25)=106.098113  U(25)=   .267370   M(25)=   .078024   MG(1)=    .061191
                6.914539          .012147           .004709          -.005641  U(13)=   .180419  UP(13)=   .126818  MG(25)=  -.050249
STEP( 226)  T=  2.035207  P(1)=107.708861  P(13)=107.175070  P(25)=106.449180  U(25)=   .267452   M(25)=   .078024   MG(1)=    .045722
                6.976338          .009455           .004452          -.002351  U(13)=   .180589  UP(13)=   .129945  MG(25)=  -.033300
STEP( 228)  T=  2.053239  P(1)=107.418777  P(13)=107.151995  P(25)=106.788956  U(25)=   .267532   M(25)=   .078024   MG(1)=    .029231
                7.038150          .006736           .004235           .000834  U(13)=   .179216  UP(13)=   .132643  MG(25)=  -.015477
STEP( 230)  T=  2.071273  P(1)=107.130244  P(13)=107.136987  P(25)=107.107371  U(25)=   .267607   M(25)=   .078024   MG(1)=    .012236
                7.099965          .004032           .004095           .003818  U(13)=   .176313  UP(13)=   .134816  MG(25)=   .002597
STEP( 232)  T=  2.089301  P(1)=106.848113  P(13)=107.132945  P(25)=107.395305  U(25)=   .267674   M(25)=   .078024   MG(1)=   -.004759
                7.161764          .001388           .004058           .006516  U(13)=   .171963  UP(13)=   .136401  MG(25)=   .020303
STEP( 234)  T=  2.107326  P(1)=106.578565  P(13)=107.140324  P(25)=107.644942  U(25)=   .267733   M(25)=   .078025   MG(1)=   -.021266
                7.223548         -.001138           .004127           .008856  U(13)=   .166330  UP(13)=   .137371  MG(25)=   .037056
STEP( 236)  T=  2.125346  P(1)=106.329199  P(13)=107.157740  P(25)=107.849817  U(25)=   .267781   M(25)=   .078026   MG(1)=   -.036821
                7.285320         -.003475           .004290           .010776  U(13)=   .159651  UP(13)=   .137740  MG(25)=   .052315
STEP( 238)  T=  2.143364  P(1)=106.108587  P(13)=107.182492  P(25)=108.004911  U(25)=   .267817   M(25)=   .078026   MG(1)=   -.050986
                7.347083         -.005543           .004522           .012230  U(13)=   .152201  UP(13)=   .137554  MG(25)=   .065601
STEP( 240)  T=  2.161380  P(1)=105.925965  P(13)=107.211320  P(25)=108.106841  U(25)=   .267841   M(25)=   .078027   MG(1)=   -.063353
                7.408838         -.007254           .004792           .013185  U(13)=   .144259  UP(13)=   .136895  MG(25)=   .076509
STEP( 242)  T=  2.179395  P(1)=105.790953  P(13)=107.240861  P(25)=108.154008  U(25)=   .267852   M(25)=   .078028   MG(1)=   -.073554
                7.470588         -.008520           .005069           .013627  U(13)=   .136079  UP(13)=   .135870  MG(25)=   .084724
STEP( 244)  T=  2.197409  P(1)=105.712926  P(13)=107.267742  P(25)=108.146578  U(25)=   .267850   M(25)=   .078028   MG(1)=   -.081262
                7.532337         -.009251           .005321           .013557  U(13)=   .127883  UP(13)=   .134593  MG(25)=   .090025
STEP( 246)  T=  2.215423  P(1)=105.659877  P(13)=107.288056  P(25)=108.086333  U(25)=   .267836   M(25)=   .078029   MG(1)=   -.086206
                7.594087         -.009373           .005519           .012993  U(13)=   .119947  UP(13)=   .132995  MG(25)=   .092292
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NPMAX =   7     TMAX =    6.4514     PMAX =     .02470       PK-PK AMPLITUDE =     .03857 AT T =    5.9418       PMEAN =    .00542
STEP( 248)  T=  2.233438  P(1)=105.756967  P(13)=107.301732  P(25)=107.976520  U(25)=    .267810   M(25)=    .078029   MG(1)=   -.088184
                7.655841         -.009838           .005639           .011964  U(13)=    .112508  UP(13)=    .131038  MG(25)=    .091505
STEP( 250)  T=  2.251456  P(1)=105.884458  P(13)=107.304938  P(25)=107.821789  U(25)=    .267774   M(25)=    .078030   MG(1)=   -.087383
                7.717602         -.007643           .005670           .010513  U(13)=    .105780  UP(13)=    .128742  MG(25)=    .087746
STEP( 252)  T=  2.269476  P(1)=106.076479  P(13)=107.298380  P(25)=107.627783  U(25)=    .267729   M(25)=    .078030   MG(1)=   -.082906
                7.779371         -.005844           .005608           .008695  U(13)=    .093953  UP(13)=    .126162  MG(25)=    .081189
STEP( 254)  T=  2.287499  P(1)=106.322033  P(13)=107.283158  P(25)=107.400814  U(25)=    .267675   M(25)=    .078030   MG(1)=   -.075781
                7.841150         -.003542           .005465           .006560  U(13)=    .095195  UP(13)=    .123385  MG(25)=    .072090
STEP( 256)  T=  2.305525  P(1)=106.607303  P(13)=107.261369  P(25)=107.149212  U(25)=    .267616   M(25)=    .078030   MG(1)=   -.065964
                7.902940         -.000869           .005261           .004210  U(13)=    .091648  UP(13)=    .120515  MG(25)=    .060790
STEP( 258)  T=  2.323554  P(1)=106.918036  P(13)=107.235990  P(25)=106.882494  U(25)=    .267554   M(25)=    .078031   MG(1)=   -.053821
                7.964743          .002043           .005023           .001710  U(13)=    .089431  UP(13)=    .117666  MG(25)=    .047695
STEP( 260)  T=  2.341587  P(1)=107.241003  P(13)=107.210698  P(25)=106.607854  U(25)=    .267489   M(25)=    .078031   MG(1)=   -.039803
                8.026556          .005070           .004786          -.000864  U(13)=    .088639  UP(13)=    .114949  MG(25)=    .033260
STEP( 262)  T=  2.359622  P(1)=107.564413  P(13)=107.189401  P(25)=106.330537  U(25)=    .267424   M(25)=    .078031   MG(1)=   -.024423
                8.088378          .008101           .004587          -.003463  U(13)=    .089330  UP(13)=    .112468  MG(25)=    .017954
STEP( 264)  T=  2.377654  P(1)=107.877640  P(13)=107.175570  P(25)=106.056013  U(25)=    .267360   M(25)=    .078031   MG(1)=   -.008235
                8.150188          .011037           .004457          -.006035  U(13)=    .091517  UP(13)=    .110305  MG(25)=    .002255
STEP( 266)  T=  2.395682  P(1)=108.171101  P(13)=107.171456  P(25)=105.790647  U(25)=    .267298   M(25)=    .078031   MG(1)=    .008195
                8.211984          .013787           .004419          -.008523  U(13)=    .095154  UP(13)=    .108517  MG(25)=   -.013363
STEP( 268)  T=  2.413706  P(1)=108.436195  P(13)=107.177437  P(25)=105.541731  U(25)=    .267240   M(25)=    .078031   MG(1)=    .024305
                8.273767          .016272           .004475          -.010855  U(13)=    .100124  UP(13)=    .107120  MG(25)=   -.028441
STEP( 270)  T=  2.431727  P(1)=108.665445  P(13)=107.191931  P(25)=105.317164  U(25)=    .267187   M(25)=    .078031   MG(1)=    .039557
                8.335539          .018420           .004610          -.012960  U(13)=    .106245  UP(13)=    .106082  MG(25)=   -.042534
STEP( 272)  T=  2.449745  P(1)=108.852605  P(13)=107.212208  P(25)=105.125433  U(25)=    .267142   M(25)=    .078030   MG(1)=    .053452
                8.397331          .020174           .004800          -.014757  U(13)=    .113285  UP(13)=    .105338  MG(25)=   -.055226
STEP( 274)  T=  2.467760  P(1)=108.992697  P(13)=107.236271  P(25)=104.975278  U(25)=    .267107   M(25)=    .078030   MG(1)=    .065545
                8.459056          .021487           .005026          -.016164  U(13)=    .120875  UP(13)=    .105025  MG(25)=   -.066132
STEP( 276)  T=  2.485775  P(1)=109.082272  P(13)=107.262873  P(25)=104.874997  U(25)=    .267083   M(25)=    .078030   MG(1)=    .075459
                8.520806          .022327           .005275          -.017104  U(13)=    .128645  UP(13)=    .105241  MG(25)=   -.074907
STEP( 278)  T=  2.503788  P(1)=109.119756  P(13)=107.289882  P(25)=104.831915  U(25)=    .267073   M(25)=    .078030   MG(1)=    .082898
                8.582552          .022678           .005528          -.017508  U(13)=    .136298  UP(13)=    .106031  MG(25)=   -.081258

NPMAX =   8     TMAX =    7.5632     PMAX =    -.00939       PK-PK AMPLITUDE =     .03409 AT T =    7.0073       PMEAN =    .00765
STEP( 280)  T=  2.521801  P(1)=109.105530  P(13)=107.313889  P(25)=104.851023  U(25)=    .267078   M(25)=    .078029   MG(1)=    .087654
                8.644298          .022545           .005753          -.017329  U(13)=    .143623  UP(13)=    .107385  MG(25)=   -.084951
STEP( 282)  T=  2.539815  P(1)=109.041824  P(13)=107.331799  P(25)=104.933608  U(25)=    .267097   M(25)=    .078029   MG(1)=    .089615
                8.706046          .021948           .005921          -.016555  U(13)=    .150454  UP(13)=    .109255  MG(25)=   -.085839
STEP( 284)  T=  2.557829  P(1)=108.932482  P(13)=107.341892  P(25)=105.076395  U(25)=    .267130   M(25)=    .078028   MG(1)=    .088765
                8.767798          .020923           .006016          -.015217  U(13)=    .156629  UP(13)=    .111561  MG(25)=   -.083867
STEP( 286)  T=  2.575846  P(1)=108.782700  P(13)=107.343748  P(25)=105.271554  U(25)=    .267176   M(25)=    .078028   MG(1)=    .085187
                8.829555          .019519           .006033          -.013387  U(13)=    .161998  UP(13)=    .114199  MG(25)=   -.079096
STEP( 288)  T=  2.593865  P(1)=108.598903  P(13)=107.337910  P(25)=105.508208  U(25)=    .267232   M(25)=    .078027   MG(1)=    .079052
                8.891320          .017797           .005979          -.011170  U(13)=    .166426  UP(13)=    .117049  MG(25)=   -.071701
STEP( 290)  T=  2.611886  P(1)=108.388695  P(13)=107.325724  P(25)=105.774345  U(25)=    .267294   M(25)=    .078027   MG(1)=    .070615
                8.953093          .015827           .005864          -.008675  U(13)=    .169794  UP(13)=    .119984  MG(25)=   -.061961
STEP( 292)  T=  2.629910  P(1)=108.160295  P(13)=107.309254  P(25)=106.058327  U(25)=    .267361   M(25)=    .078027   MG(1)=    .060208
                9.014877          .013686           .005710          -.006014  U(13)=    .171996  UP(13)=    .122875  MG(25)=   -.050244
STEP( 294)  T=  2.647937  P(1)=107.921084  P(13)=107.291174  P(25)=106.349491  U(25)=    .267429   M(25)=    .078026   MG(1)=    .048215
                9.076671          .011444           .005541          -.003285  U(13)=    .172951  UP(13)=    .125599  MG(25)=   -.036982
STEP( 296)  T=  2.665967  P(1)=107.676353  P(13)=107.274509  P(25)=106.638095  U(25)=    .267497   M(25)=    .078027   MG(1)=    .035054
                9.138476          .009150           .005384          -.000580  U(13)=    .172608  UP(13)=    .128046  MG(25)=   -.022652
STEP( 298)  T=  2.684001  P(1)=107.429835  P(13)=107.262152  P(25)=106.915241  U(25)=    .267562   M(25)=    .078027   MG(1)=    .021140
                9.200292          .006840           .005269           .002017  U(13)=    .170959  UP(13)=    .130122  MG(25)=   -.007757
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LINEAR COMB. RESP., 20.0 MICRON PARTICLES, 0.05 AMPL.

COMPUTATION STEP(300) WHERE TIME(NON-DIMENSIONAL)= .2702E+01 DT= .9016E-02 T(MIL-SEC)= .4324E+01

REGION(1) WHERE SMB= -.10000E+01 SMC= 0. CMB= .10000E+01

INDEX M	X STR	MACH NO.	PRESSURE	DENSITY	VELOCITY	ENTROPY	ENTHALPY	A(LOC)
1	-.195800E+01	0.	.107186E+03	.912135E+01	0.	.195550E+01	.117511E+02	.342798E+01
2	-.187642E+01	.449674E-02	.107185E+03	.912128E+01	.154147E-01	.195550E+01	.117511E+02	.342798E+01
3	-.179483E+01	.897222E-02	.107184E+03	.912115E+01	.307568E-01	.195552E+01	.117512E+02	.342800E+01
4	-.171325E+01	.134165E-01	.107183E+03	.912092E+01	.459920E-01	.195554E+01	.117513E+02	.342802E+01
5	-.163167E+01	.178121E-01	.107182E+03	.912065E+01	.610610E-01	.195557E+01	.117516E+02	.342806E+01
6	-.155008E+01	.221427E-01	.107183E+03	.912040E+01	.759077E-01	.195560E+01	.117520E+02	.342811E+01
7	-.146850E+01	.263895E-01	.107184E+03	.912021E+01	.904080E-01	.195565E+01	.117524E+02	.342818E+01
8	-.138692E+01	.305324E-01	.107189E+03	.912012E+01	.104673E+00	.195570E+01	.117530E+02	.342826E+01
9	-.130533E+01	.345504E-01	.107196E+03	.912018E+01	.118451E+00	.195575E+01	.117537E+02	.342836E+01
10	-.122375E+01	.384231E-01	.107206E+03	.912043E+01	.131733E+00	.195581E+01	.117545E+02	.342848E+01
11	-.114217E+01	.421325E-01	.107219E+03	.912088E+01	.144456E+00	.195588E+01	.117554E+02	.342861E+01
12	-.106058E+01	.456645E-01	.107236E+03	.912154E+01	.156572E+00	.195595E+01	.117564E+02	.342875E+01
13	-.979000E+00	.490093E-01	.107256E+03	.912241E+01	.168049E+00	.195602E+01	.117574E+02	.342891E+01
14	-.897417E+00	.521643E-01	.107279E+03	.912344E+01	.178876E+00	.195609E+01	.117586E+02	.342908E+01
15	-.815833E+00	.551319E-01	.107303E+03	.912454E+01	.189061E+00	.195616E+01	.117598E+02	.342925E+01
16	-.734250E+00	.579214E-01	.107326E+03	.912562E+01	.198637E+00	.195624E+01	.117610E+02	.342942E+01
17	-.652667E+00	.605468E-01	.107347E+03	.912651E+01	.207651E+00	.195631E+01	.117621E+02	.342959E+01
18	-.571083E+00	.630250E-01	.107363E+03	.912708E+01	.216159E+00	.195638E+01	.117631E+02	.342974E+01
19	-.489500E+00	.653766E-01	.107371E+03	.912716E+01	.224233E+00	.195645E+01	.117639E+02	.342986E+01
20	-.407917E+00	.676222E-01	.107371E+03	.912661E+01	.231941E+00	.195652E+01	.117646E+02	.342996E+01
21	-.326333E+00	.697835E-01	.107360E+03	.912530E+01	.239359E+00	.195659E+01	.117651E+02	.343002E+01
22	-.244750E+00	.718827E-01	.107335E+03	.912310E+01	.246561E+00	.195666E+01	.117652E+02	.343005E+01
23	-.163167E+00	.739422E-01	.107297E+03	.911992E+01	.253624E+00	.195673E+01	.117651E+02	.343003E+01
24	-.815833E-01	.759832E-01	.107243E+03	.911567E+01	.260620E+00	.195680E+01	.117647E+02	.342997E+01
25	0.	.780276E-01	.107173E+03	.911028E+01	.267622E+00	.195688E+01	.117639E+02	.342986E+01

INDEX OF DISCONTINUITY DIRECTION= 0 AND DISCONTINUITY LOCATION= 0.

INDEX M	X STR	PARTICLE DENSITY	PARTICLE VELOCITY	SMDG	SMDP	SMDDG
1	-.195800E+01	.399049E+01	0.	.620167E-01	.223260E-01	-.486597E-01
2	-.187642E+01	.396337E+01	.995015E-02	.620147E-01	.223253E-01	-.477477E-01
3	-.179483E+01	.391901E+01	.205453E-01	.620126E-01	.223245E-01	-.468357E-01
4	-.171325E+01	.388873E+01	.314988E-01	.620066E-01	.223224E-01	-.448967E-01
5	-.163167E+01	.386714E+01	.426787E-01	.619980E-01	.223193E-01	-.422730E-01
6	-.155008E+01	.385071E+01	.539993E-01	.619876E-01	.223155E-01	-.393182E-01
7	-.146850E+01	.383750E+01	.653865E-01	.619701E-01	.223092E-01	-.350385E-01
8	-.138692E+01	.382691E+01	.767715E-01	.619525E-01	.223029E-01	-.307588E-01
9	-.130533E+01	.381828E+01	.880982E-01	.619306E-01	.222950E-01	-.254015E-01
10	-.122375E+01	.381119E+01	.993059E-01	.619076E-01	.222868E-01	-.197749E-01
11	-.114217E+01	.380654E+01	.110348E+00	.618856E-01	.222788E-01	-.138171E-01
12	-.106058E+01	.380159E+01	.121175E+00	.618649E-01	.222714E-01	-.736280E-02
13	-.979000E+00	.380373E+01	.131755E+00	.618442E-01	.222639E-01	-.908488E-03
14	-.897417E+00	.379876E+01	.142041E+00	.618359E-01	.222609E-01	.574263E-02
15	-.815833E+00	.380752E+01	.152036E+00	.618277E-01	.222580E-01	.123937E-01
16	-.734250E+00	.381172E+01	.161700E+00	.618297E-01	.222587E-01	.187125E-01
17	-.652667E+00	.381316E+01	.171032E+00	.618384E-01	.222618E-01	.248096E-01
18	-.571083E+00	.383458E+01	.180073E+00	.618503E-01	.222661E-01	.306534E-01
19	-.489500E+00	.384362E+01	.188786E+00	.618742E-01	.222747E-01	.354839E-01
20	-.407917E+00	.386303E+01	.197228E+00	.618981E-01	.222833E-01	.403144E-01
21	-.326333E+00	.388001E+01	.205374E+00	.619266E-01	.222936E-01	.437098E-01
22	-.244750E+00	.390434E+01	.213386E+00	.619563E-01	.223043E-01	.467463E-01
23	-.163167E+00	.390842E+01	.221273E+00	.619838E-01	.223142E-01	.489515E-01
24	-.815833E-01	.392778E+01	.229155E+00	.620082E-01	.223230E-01	.499096E-01
25	0.	.393260E+01	.237890E+00	.620327E-01	.223318E-01	.508677E-01

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IBS       XSTRBS        F SMOG         R            TEMP SUR.     PRESS(LOC)
  1   -.195800E+01  .620167E-01  .140694E+01  .266865E+01  .107186E+03
  2   -.176220E+01  .620113E-01  .148682E+01  .266863E+01  .107184E+03
  3   -.156640E+01  .619911E-01  .148632E+01  .266853E+01  .107183E+03
  4   -.137060E+01  .619490E-01  .148531E+01  .266834E+01  .107190E+03
  5   -.117480E+01  .618938E-01  .148393E+01  .266803E+01  .107214E+03
  6   -.979000E+00  .618442E-01  .148280E+01  .266787E+01  .107256E+03
  7   -.783200E+00  .619244E-01  .148233E+01  .266778E+01  .107312E+03
  8   -.587400E+00  .618455E-01  .148283E+01  .266788E+01  .107359E+03
  9   -.391600E+00  .619029E-01  .148421E+01  .266813E+01  .107369E+03
 10   -.195800E+00  .619740E-01  .140591E+01  .266846E+01  .107312E+03
 11   0.            .620327E-01  .148732E+01  .266872E+01  .107173E+03
STEP( 300)  T=  2.702033  P(1)=107.185567  P(13)=107.256262  P(25)=107.172761  U(25)=  .267622  M(25)=  .078027  MG(1)=  .006928
                9.262104          .004551           .005213           .004431  U(13)=  .168049  UP(13)=  .131755  MG(25)=  .007187
STEP( 302)  T=  2.720062  P(1)=106.948951  P(13)=107.257797  P(25)=107.403419  U(25)=  .267676  M(25)=  .078027  MG(1)=  -.007185
                9.323932          .002333           .005228           .006592  U(13)=  .163384  UP(13)=  .132900  MG(25)=  .021677
STEP( 304)  T=  2.738087  P(1)=106.726619  P(13)=107.266454  P(25)=107.600999  U(25)=  .267722  M(25)=  .078028  MG(1)=  -.020779
                9.385689          .000249           .005309           .008444  U(13)=  .159930  UP(13)=  .133545  MG(25)=  .035238
STEP( 306)  T=  2.756109  P(1)=106.525878  P(13)=107.281012  P(25)=107.760319  U(25)=  .267760  M(25)=  .078029  MG(1)=  -.033459
                9.447467         -.001632           .005445           .009937  U(13)=  .153094  UP(13)=  .133703  MG(25)=  .047437
STEP( 308)  T=  2.774129  P(1)=106.354370  P(13)=107.299761  P(25)=107.877337  U(25)=  .267787  M(25)=  .078029  MG(1)=  -.044853
                9.509237         -.003239           .005621           .011034  U(13)=  .146707  UP(13)=  .133417  MG(25)=  .057894
STEP( 310)  T=  2.792148  P(1)=106.219863  P(13)=107.320652  P(25)=107.949351  U(25)=  .267804  M(25)=  .078030  MG(1)=  -.054619
                9.571001         -.004500           .005817           .011709  U(13)=  .139993  UP(13)=  .132750  MG(25)=  .066293
STEP( 312)  T=  2.810166  P(1)=106.129838  P(13)=107.341223  P(25)=107.975158  U(25)=  .267810  M(25)=  .078030  MG(1)=  -.062451
                9.632763         -.005344           .006010           .011951  U(13)=  .133149  UP(13)=  .131783  MG(25)=  .072391
STEP( 314)  T=  2.828183  P(1)=106.090762  P(13)=107.358728  P(25)=107.955080  U(25)=  .267805  M(25)=  .078031  MG(1)=  -.068090
                9.694523         -.005710           .006174           .011763  U(13)=  .126347  UP(13)=  .130607  MG(25)=  .076026

NPMAX =   9     TMAX =   8.5826     PMAX =    .02268      PK-PK AMPLITUDE =    .03207 AT T =   8.0729     PMEAN =    .00664
STEP( 316)  T=  2.846201  P(1)=106.107159  P(13)=107.370907  P(25)=107.890872  U(25)=  .267790  M(25)=  .078031  MG(1)=  -.071332
                9.756286         -.005556           .006288           .011161  U(13)=  .119793  UP(13)=  .129208  MG(25)=  .077121
STEP( 318)  T=  2.864220  P(1)=106.160719  P(13)=107.376419  P(25)=107.785612  U(25)=  .267766  M(25)=  .078032  MG(1)=  -.072045
                9.818053         -.004867           .006339           .010174  U(13)=  .113700  UP(13)=  .127551  MG(25)=  .075680
STEP( 320)  T=  2.882241  P(1)=106.309173  P(13)=107.374951  P(25)=107.643637  U(25)=  .267732  M(25)=  .078032  MG(1)=  -.070181
                9.879826         -.003663           .006326           .008844  U(13)=  .108255  UP(13)=  .125651  MG(25)=  .071795
STEP( 322)  T=  2.900265  P(1)=106.486137  P(13)=107.367075  P(25)=107.470301  U(25)=  .267692  M(25)=  .078033  MG(1)=  -.065790
                9.941606         -.002004           .006252           .007219  U(13)=  .103628  UP(13)=  .123553  MG(25)=  .065631
STEP( 324)  T=  2.918290  P(1)=106.702278  P(13)=107.354051  P(25)=107.271395  U(25)=  .267645  M(25)=  .078033  MG(1)=  -.059023
               10.003396          .000021           .006130           .005355  U(13)=  .099964  UP(13)=  .121325  MG(25)=  .057426
STEP( 326)  T=  2.936319  P(1)=106.946698  P(13)=107.337700  P(25)=107.052772  U(25)=  .267594  M(25)=  .078033  MG(1)=  -.050128
               10.065195          .002314           .005977           .003306  U(13)=  .097382  UP(13)=  .119049  MG(25)=  .047475
STEP( 328)  T=  2.954351  P(1)=107.209211  P(13)=107.320335  P(25)=106.821277  U(25)=  .267539  M(25)=  .078033  MG(1)=  -.039432
               10.127005          .004772           .005814           .001137  U(13)=  .095978  UP(13)=  .116811  MG(25)=  .036122
STEP( 330)  T=  2.972385  P(1)=107.479009  P(13)=107.304544  P(25)=106.583781  U(25)=  .267484  M(25)=  .078034  MG(1)=  -.027326
               10.188823          .007301           .005666          -.001099  U(13)=  .095913  UP(13)=  .114696  MG(25)=  .023749
STEP( 332)  T=  2.990420  P(1)=107.746818  P(13)=107.292786  P(25)=106.345821  U(25)=  .267428  M(25)=  .078034  MG(1)=  -.014246
               10.250642          .009811           .005556          -.003319  U(13)=  .096915  UP(13)=  .112780  MG(25)=  .010756
STEP( 334)  T=  3.008450  P(1)=108.003911  P(13)=107.286984  P(25)=106.112872  U(25)=  .267373  M(25)=  .078034  MG(1)=  -.000656
               10.312448          .012220           .005501          -.005503  U(13)=  .099262  UP(13)=  .111119  MG(25)=  -.002450
STEP( 336)  T=  3.026478  P(1)=108.242403  P(13)=107.288074  P(25)=105.891338  U(25)=  .267322  M(25)=  .078034  MG(1)=  .012975
               10.374243          .014456           .005511          -.007579  U(13)=  .102782  UP(13)=  .109745  MG(25)=  -.015466
STEP( 338)  T=  3.044502  P(1)=108.455267  P(13)=107.295720  P(25)=105.688275  U(25)=  .267274  M(25)=  .078034  MG(1)=  .026186
               10.436028          .016450           .005583          -.009482  U(13)=  .107354  UP(13)=  .108655  MG(25)=  -.027897
STEP( 340)  T=  3.062524  P(1)=108.636394  P(13)=107.308413  P(25)=105.510801  U(25)=  .267232  M(25)=  .078034  MG(1)=  .038538
               10.497804          .018148           .005702          -.011145  U(13)=  .112815  UP(13)=  .107804  MG(25)=  -.039365
STEP( 342)  T=  3.080544  P(1)=108.780643  P(13)=107.325008  P(25)=105.365917  U(25)=  .267198  M(25)=  .078033  MG(1)=  .049628
               10.559572          .019500           .005858          -.012503  U(13)=  .118906  UP(13)=  .107262  MG(25)=  -.049518
STEP( 344)  T=  3.098562  P(1)=108.884001  P(13)=107.344626  P(25)=105.260436  U(25)=  .267174  M(25)=  .078033  MG(1)=  .059102
               10.621334          .020469           .006041          -.013492  U(13)=  .125326  UP(13)=  .107127  MG(25)=  -.058038
STEP( 346)  T=  3.116579  P(1)=108.943696  P(13)=107.365439  P(25)=105.200252  U(25)=  .267160  M(25)=  .078033  MG(1)=  .066664
               10.683093          .021030           .006237          -.014056  U(13)=  .131820  UP(13)=  .107451  MG(25)=  -.064645
STEP( 348)  T=  3.134595  P(1)=108.959423  P(13)=107.384926  P(25)=105.189735  U(25)=  .267157  M(25)=  .078033  MG(1)=  .072088
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              10.744850          .021175            .006419              -.014154  U(13)=    .138188  UP(13)=    .108248  MG(25)=  -.069116

NPMAX =  10    TMAX =    9.6945    PMAX =  -.00571    PK-PK AMPLITUDE =    .02839 AT T =    9.1385     PMEAN =    .00848
STEP( 350)  T=  3.152611  P(1)=108.931383  P(13)=107.400837  P(25)=105.230906  U(25)=    .267167   M(25)=    .078032   MG(1)=    .075225
              10.806607          .020913            .006568              -.013768  U(13)=    .144251  UP(13)=    .109497  MG(25)=  -.071288
STEP( 352)  T=  3.170628  P(1)=108.862189  P(13)=107.411659  P(25)=105.322714  U(25)=    .267188   M(25)=    .078032   MG(1)=    .076008
              10.868367          .020264            .006670              -.012908  U(13)=    .143852  UP(13)=    .111150  MG(25)=  -.071077
STEP( 354)  T=  3.188647  P(1)=108.755675  P(13)=107.416675  P(25)=105.460808  U(25)=    .267221   M(25)=    .078032   MG(1)=    .074449
              10.930130          .019266            .006717              -.011614  U(13)=    .154845  UP(13)=    .113135  MG(25)=  -.068484
STEP( 356)  T=  3.206666  P(1)=108.616877  P(13)=107.415944  P(25)=105.638061  U(25)=    .267262   M(25)=    .078031   MG(1)=    .070646
              10.991898          .017965            .006710              -.009953  U(13)=    .159101  UP(13)=    .115360  MG(25)=  -.063602
STEP( 358)  T=  3.224688  P(1)=108.451891  P(13)=107.410175  P(25)=105.845683  U(25)=    .267311   M(25)=    .078031   MG(1)=    .064768
              11.053674          .016419            .006656              -.008007  U(13)=    .162504  UP(13)=    .117725  MG(25)=  -.056616
STEP( 360)  T=  3.242712  P(1)=108.267424  P(13)=107.400573  P(25)=106.074386  U(25)=    .267364   M(25)=    .078031   MG(1)=    .057056
              11.115457          .014690            .006566              -.005863  U(13)=    .164953  UP(13)=    .120125  MG(25)=  -.047786
STEP( 362)  T=  3.260739  P(1)=108.069689  P(13)=107.388763  P(25)=106.315079  U(25)=    .267421   M(25)=    .078031   MG(1)=    .047804
              11.177249          .012837            .006455              -.003608  U(13)=    .165368  UP(13)=    .122455  MG(25)=  -.037440
STEP( 364)  T=  3.278768  P(1)=107.863570  P(13)=107.376702  P(25)=106.559215  U(25)=    .267478   M(25)=    .078031   MG(1)=    .037340
              11.239051          .010905            .006342              -.001319  U(13)=    .166694  UP(13)=    .124616  MG(25)=  -.025953
STEP( 366)  T=  3.296800  P(1)=107.653017  P(13)=107.366453  P(25)=106.798833  U(25)=    .267534   M(25)=    .078031   MG(1)=    .026014
              11.300862          .008932            .006246               .000926  U(13)=    .165913  UP(13)=    .126521  MG(25)=  -.013730
STEP( 368)  T=  3.314834  P(1)=107.442124  P(13)=107.359822  P(25)=107.026552  U(25)=    .267588   M(25)=    .078031   MG(1)=    .014184
              11.362679          .006955            .006184               .003060  U(13)=    .164045  UP(13)=    .128098  MG(25)=  -.001198
STEP( 370)  T=  3.332866  P(1)=107.235772  P(13)=107.358006  P(25)=107.235668  U(25)=    .267637   M(25)=    .078032   MG(1)=    .002216
              11.424489          .005021            .006167               .005320  U(13)=    .161158  UP(13)=    .129298  MG(25)=    .011216
STEP( 372)  T=  3.350855  P(1)=107.039532  P(13)=107.361406  P(25)=107.420290  U(25)=    .267680   M(25)=    .078032   MG(1)=  -.009530
              11.486288          .003182            .006199               .006751  U(13)=    .157368  UP(13)=    .130091  MG(25)=    .023098
STEP( 374)  T=  3.368921  P(1)=106.859453  P(13)=107.369687  P(25)=107.575330  U(25)=    .267716   M(25)=    .078033   MG(1)=  -.020703
              11.548078          .001494            .006276               .008204  U(13)=    .152827  UP(13)=    .130473  MG(25)=    .034062
STEP( 376)  T=  3.386945  P(1)=106.701844  P(13)=107.381939  P(25)=107.696581  U(25)=    .267745   M(25)=    .078033   MG(1)=  -.030971
              11.609861          .000017            .006391               .009340  U(13)=    .147715  UP(13)=    .130462  MG(25)=    .043758
STEP( 378)  T=  3.404967  P(1)=106.573045  P(13)=107.396759  P(25)=107.780884  U(25)=    .267764   M(25)=    .078034   MG(1)=  -.040023
              11.671638         -.001190            .006530               .010130  U(13)=    .142215  UP(13)=    .130093  MG(25)=    .051886
STEP( 380)  T=  3.422988  P(1)=106.479109  P(13)=107.412301  P(25)=107.826336  U(25)=    .267775   M(25)=    .078034   MG(1)=  -.047578
              11.733412         -.002070            .006676               .010556  U(13)=    .136500  UP(13)=    .129417  MG(25)=    .058200
STEP( 382)  T=  3.441009  P(1)=106.425360  P(13)=107.426484  P(25)=107.832399  U(25)=    .267777   M(25)=    .078035   MG(1)=  -.053396
              11.795183         -.002574            .006809               .010613  U(13)=    .130727  UP(13)=    .128494  MG(25)=    .062521
STEP( 384)  T=  3.459029  P(1)=106.415811  P(13)=107.437361  P(25)=107.799887  U(25)=    .267769   M(25)=    .078035   MG(1)=  -.057279
              11.856955         -.002663            .006911               .010308  U(13)=    .125044  UP(13)=    .127397  MG(25)=    .064736

NPMAX =  11    TMAX =   10.7449    PMAX =    .02118    PK-PK AMPLITUDE =    .02689 AT T =   10.2197     PMEAN =    .00773
STEP( 386)  T=  3.477051  P(1)=106.452558  P(13)=107.443678  P(25)=107.730888  U(25)=    .267753   M(25)=    .078036   MG(1)=  -.059089
              11.918730         -.002319            .006970               .009662  U(13)=    .119629  UP(13)=    .126141  MG(25)=    .064808
STEP( 388)  T=  3.495074  P(1)=106.535304  P(13)=107.445095  P(25)=107.628641  U(25)=    .267729   M(25)=    .078036   MG(1)=  -.058751
              11.980509         -.001544            .006983               .008703  U(13)=    .114666  UP(13)=    .124703  MG(25)=    .062769
STEP( 390)  T=  3.513098  P(1)=106.660807  P(13)=107.441737  P(25)=107.497327  U(25)=    .267698   M(25)=    .078037   MG(1)=  -.056264
              12.042293         -.000367            .006952               .007473  U(13)=    .110319  UP(13)=    .123098  MG(25)=    .058722
STEP( 392)  T=  3.531124  P(1)=106.823103  P(13)=107.434265  P(25)=107.341703  U(25)=    .267661   M(25)=    .078037   MG(1)=  -.051711
              12.104084          .001154            .006882               .006014  U(13)=    .106728  UP(13)=    .121362  MG(25)=    .052832
STEP( 394)  T=  3.549153  P(1)=107.014444  P(13)=107.423786  P(25)=107.166512  U(25)=    .267620   M(25)=    .078037   MG(1)=  -.045254
              12.165883          .002947            .006783               .004372  U(13)=    .104014  UP(13)=    .119549  MG(25)=    .045320
STEP( 396)  T=  3.567184  P(1)=107.226303  P(13)=107.411761  P(25)=106.976109  U(25)=    .267576   M(25)=    .078037   MG(1)=  -.037125
              12.227691          .004933            .006671               .002588  U(13)=    .102268  UP(13)=    .117724  MG(25)=    .036447
STEP( 398)  T=  3.585218  P(1)=107.450074  P(13)=107.399912  P(25)=106.775050  U(25)=    .267529   M(25)=    .078038   MG(1)=  -.027621
              12.289507          .007030            .006560               .000703  U(13)=    .101557  UP(13)=    .115953  MG(25)=    .026585
```

LINEAR COMB. RESP., 20.0 MICRON PARTICLES, 0.05 AMPL.

COMPUTATION STEP(400) WHERE TIME(NON-DIMENSIONAL)= .3603E+01 DT= .9018E-02 T(MIL-SEC)= .5766E+01

REGION(1) WHERE SMB= -.10000E+01 SMC= 0. CMB= .10000E+01

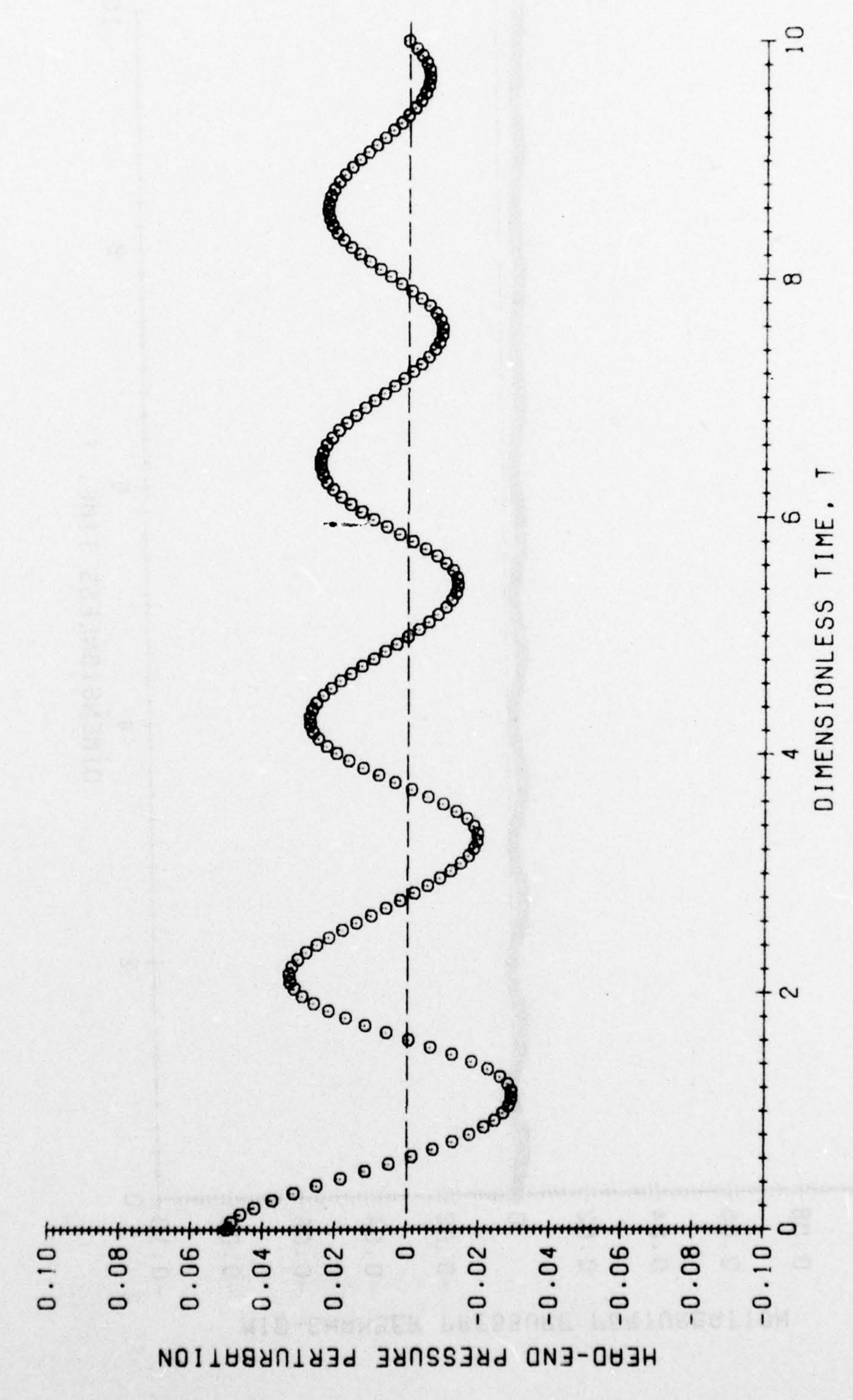
INDEX M	X STR	MACH NO.	PRESSURE	DENSITY	VELOCITY	ENTROPY	ENTHALPY	A(LOC)
1	-.195900E+01	0.	.107677E+03	.915620E+01	0.	.195539E+01	.117601E+02	.342929E+01
2	-.187642E+01	.201287E-02	.107675E+03	.915603E+01	.690271E-02	.195539E+01	.117600E+02	.342929E+01
3	-.179483E+01	.404973E-02	.107667E+03	.915543E+01	.138876E-01	.195540E+01	.117599E+02	.342928E+01
4	-.171325E+01	.612756E-02	.107655E+03	.915448E+01	.210130E-01	.195541E+01	.117598E+02	.342925E+01
5	-.163167E+01	.826834E-02	.107638E+03	.915319E+01	.283540E-01	.195543E+01	.117596E+02	.342923E+01
6	-.155008E+01	.104914E-01	.107617E+03	.915160E+01	.359770E-01	.195545E+01	.117594E+02	.342920E+01
7	-.146850E+01	.128165E-01	.107593E+03	.914973E+01	.439500E-01	.195548E+01	.117592E+02	.342916E+01
8	-.138692E+01	.152617E-01	.107566E+03	.914761E+01	.523345E-01	.195551E+01	.117589E+02	.342913E+01
9	-.130533E+01	.178423E-01	.107536E+03	.914528E+01	.611827E-01	.195554E+01	.117586E+02	.342909E+01
10	-.122375E+01	.205714E-01	.107503E+03	.914273E+01	.705404E-01	.195558E+01	.117583E+02	.342904E+01
11	-.114217E+01	.234581E-01	.107468E+03	.913999E+01	.804378E-01	.195563E+01	.117580E+02	.342900E+01
12	-.106058E+01	.265076E-01	.107431E+03	.913704E+01	.908934E-01	.195567E+01	.117577E+02	.342895E+01
13	-.979000E+00	.297221E-01	.107390E+03	.913386E+01	.101914E+00	.195572E+01	.117574E+02	.342890E+01
14	-.897417E+00	.330990E-01	.107346E+03	.913043E+01	.113491E+00	.195577E+01	.117570E+02	.342884E+01
15	-.815833E+00	.366329E-01	.107298E+03	.912672E+01	.125606E+00	.195583E+01	.117565E+02	.342878E+01
16	-.734250E+00	.403159E-01	.107247E+03	.912272E+01	.138231E+00	.195589E+01	.117560E+02	.342870E+01
17	-.652667E+00	.441366E-01	.107191E+03	.911840E+01	.151327E+00	.195595E+01	.117554E+02	.342862E+01
18	-.571083E+00	.480832E-01	.107131E+03	.911378E+01	.164855E+00	.195601E+01	.117548E+02	.342852E+01
19	-.489500E+00	.521394E-01	.107066E+03	.910886E+01	.178756E+00	.195607E+01	.117541E+02	.342842E+01
20	-.407917E+00	.562926E-01	.106998E+03	.910359E+01	.192989E+00	.195614E+01	.117533E+02	.342831E+01
21	-.326333E+00	.605305E-01	.106923E+03	.909794E+01	.207510E+00	.195621E+01	.117525E+02	.342819E+01
22	-.244750E+00	.648382E-01	.106844E+03	.909187E+01	.222269E+00	.195629E+01	.117516E+02	.342805E+01
23	-.163167E+00	.692026E-01	.106758E+03	.908537E+01	.237220E+00	.195637E+01	.117505E+02	.342791E+01
24	-.815833E-01	.736080E-01	.106666E+03	.907842E+01	.252310E+00	.195645E+01	.117494E+02	.342775E+01
25	0.	.780378E-01	.106569E+03	.907106E+01	.267480E+00	.195654E+01	.117483E+02	.342758E+01

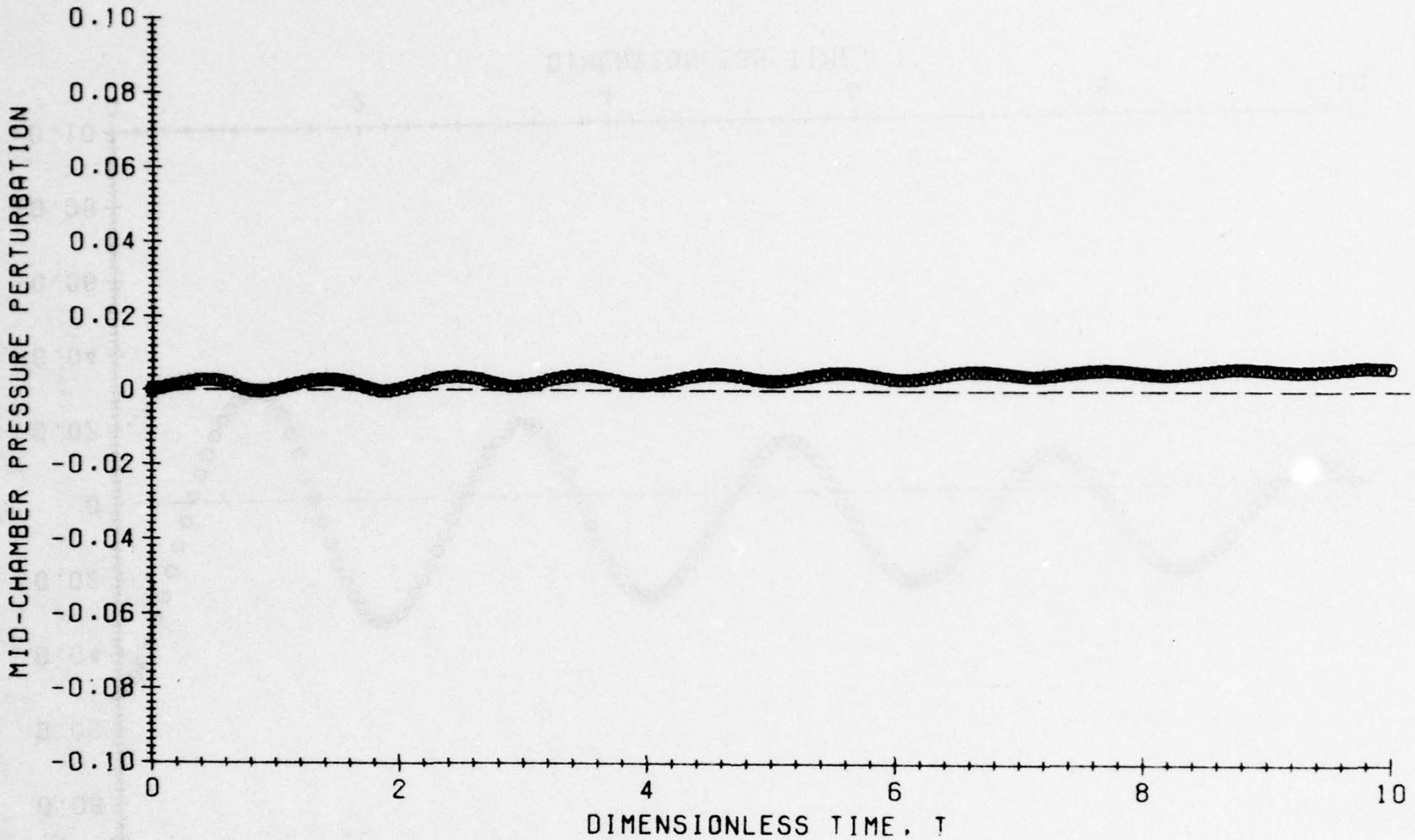
INDEX OF DISCONTINUITY DIRECTION= 0 AND DISCONTINUITY LOCATION= 0.

INDEX M	X STR	PARTICLE DENSITY	PARTICLE VELOCITY	SMOG	SMOP	SMOOG
1	-.195800E+01	.396060E+01	0.	.605379E-01	.217937E-01	.367171E-01
2	-.187642E+01	.393013E+01	.892274E-02	.605651E-01	.218034E-01	.359187E-01
3	-.179483E+01	.387895E+01	.180971E-01	.605923E-01	.218132E-01	.351203E-01
4	-.171325E+01	.384329E+01	.273846E-01	.606497E-01	.218339E-01	.334630E-01
5	-.163167E+01	.381823E+01	.367479E-01	.607273E-01	.218618E-01	.312330E-01
6	-.155008E+01	.380000E+01	.461773E-01	.608140E-01	.218930E-01	.287533E-01
7	-.146850E+01	.378657E+01	.556731E-01	.609371E-01	.219373E-01	.252754E-01
8	-.138692E+01	.377648E+01	.652435E-01	.610601E-01	.219816E-01	.217975E-01
9	-.130533E+01	.376989E+01	.748931E-01	.612069E-01	.220345E-01	.176214E-01
10	-.122375E+01	.376389E+01	.846254E-01	.613596E-01	.220895E-01	.132709E-01
11	-.114217E+01	.376393E+01	.944460E-01	.615156E-01	.221456E-01	.875653E-02
12	-.106058E+01	.375976E+01	.104333E+00	.616765E-01	.222035E-01	.399643E-02
13	-.979000E+00	.376310E+01	.114296E+00	.618374E-01	.222615E-01	-.763683E-03
14	-.897417E+00	.376982E+01	.124302E+00	.619831E-01	.223139E-01	-.546851E-02
15	-.815833E+00	.376744E+01	.134306E+00	.621288E-01	.223664E-01	-.101733E-01
16	-.734250E+00	.378016E+01	.144316E+00	.622547E-01	.224117E-01	-.145819E-01
17	-.652667E+00	.378973E+01	.154236E+00	.623674E-01	.224523E-01	-.187931E-01
18	-.571083E+00	.379961E+01	.164003E+00	.624712E-01	.224896E-01	-.228242E-01
19	-.489500E+00	.380678E+01	.173651E+00	.625390E-01	.225140E-01	-.261351E-01
20	-.407917E+00	.382729E+01	.183572E+00	.626068E-01	.225384E-01	-.294461E-01
21	-.326333E+00	.383807E+01	.193735E+00	.626326E-01	.225477E-01	-.318009E-01
22	-.244750E+00	.385134E+01	.204169E+00	.626479E-01	.225532E-01	-.339167E-01
23	-.163167E+00	.385584E+01	.214869E+00	.626416E-01	.225510E-01	-.354871E-01
24	-.815833E-01	.386398E+01	.225879E+00	.626029E-01	.225370E-01	-.362395E-01
25	0.	.386703E+01	.236454E+00	.625642E-01	.225231E-01	-.369919E-01

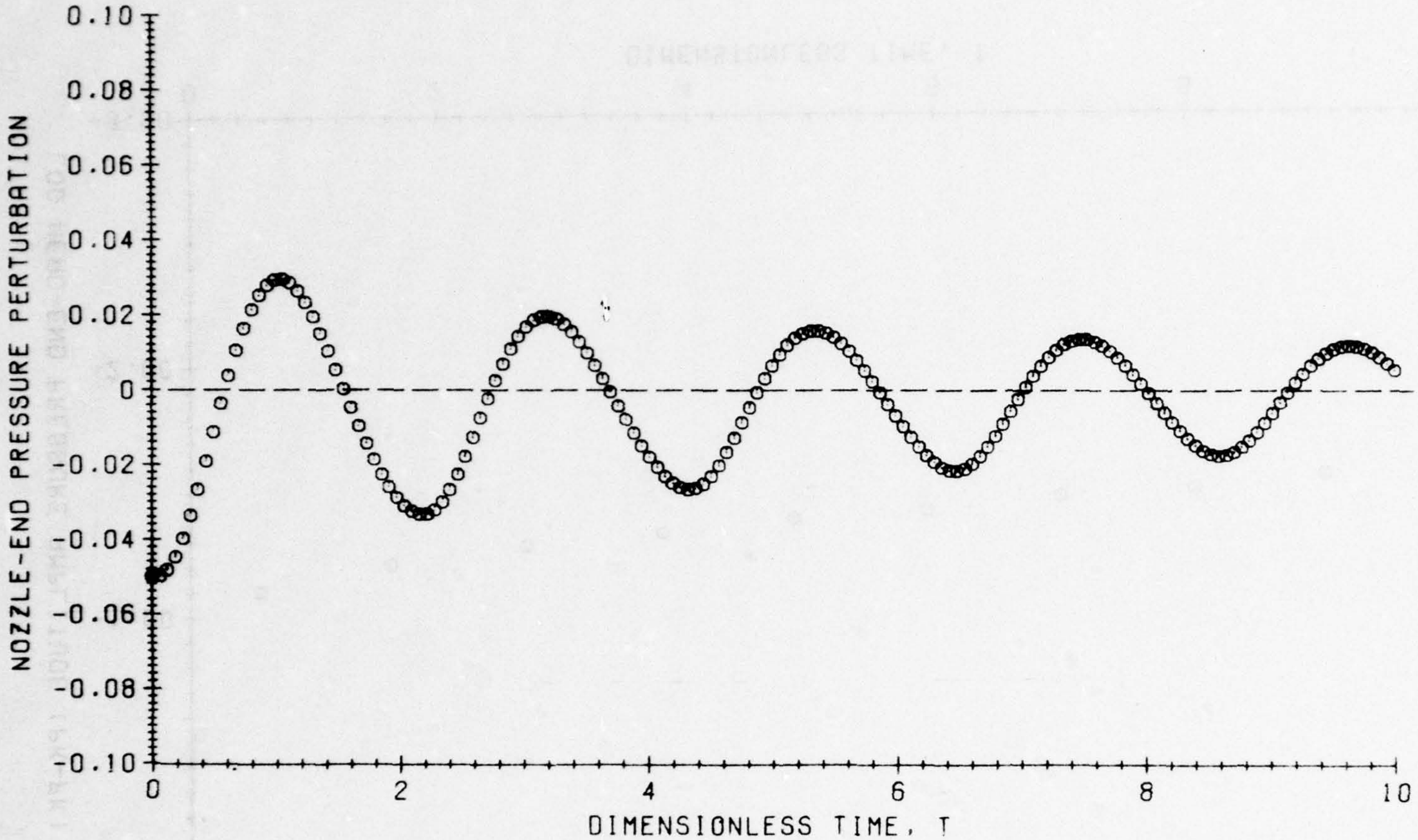
IOS	XSTFES	F SMOG	H	TEMP SUR.	PRESS(LOC)
1	-.195800E+01	.605379E-01	.145148E+01	.266197E+01	.107677E+03
2	-.176220E+01	.606032E-01	.145305E+01	.266227E+01	.107662E+03
3	-.156640E+01	.607894E-01	.145751E+01	.266311E+01	.107621E+03
4	-.137060E+01	.610847E-01	.146459E+01	.266444E+01	.107560E+03
5	-.117480E+01	.614512E-01	.147338E+01	.266610E+01	.107482E+03
6	-.979000E+00	.618374E-01	.148264E+01	.266784E+01	.107390E+03
7	-.783200E+00	.621871E-01	.149102E+01	.266942E+01	.107278E+03
8	-.587400E+00	.624576E-01	.149751E+01	.267064E+01	.107143E+03
9	-.391600E+00	.626203E-01	.150141E+01	.267137E+01	.106983E+03
10	-.195800E+00	.626570E-01	.150229E+01	.267154E+01	.106792E+03
11	0.	.625642E-01	.150006E+01	.267112E+01	.106569E+03

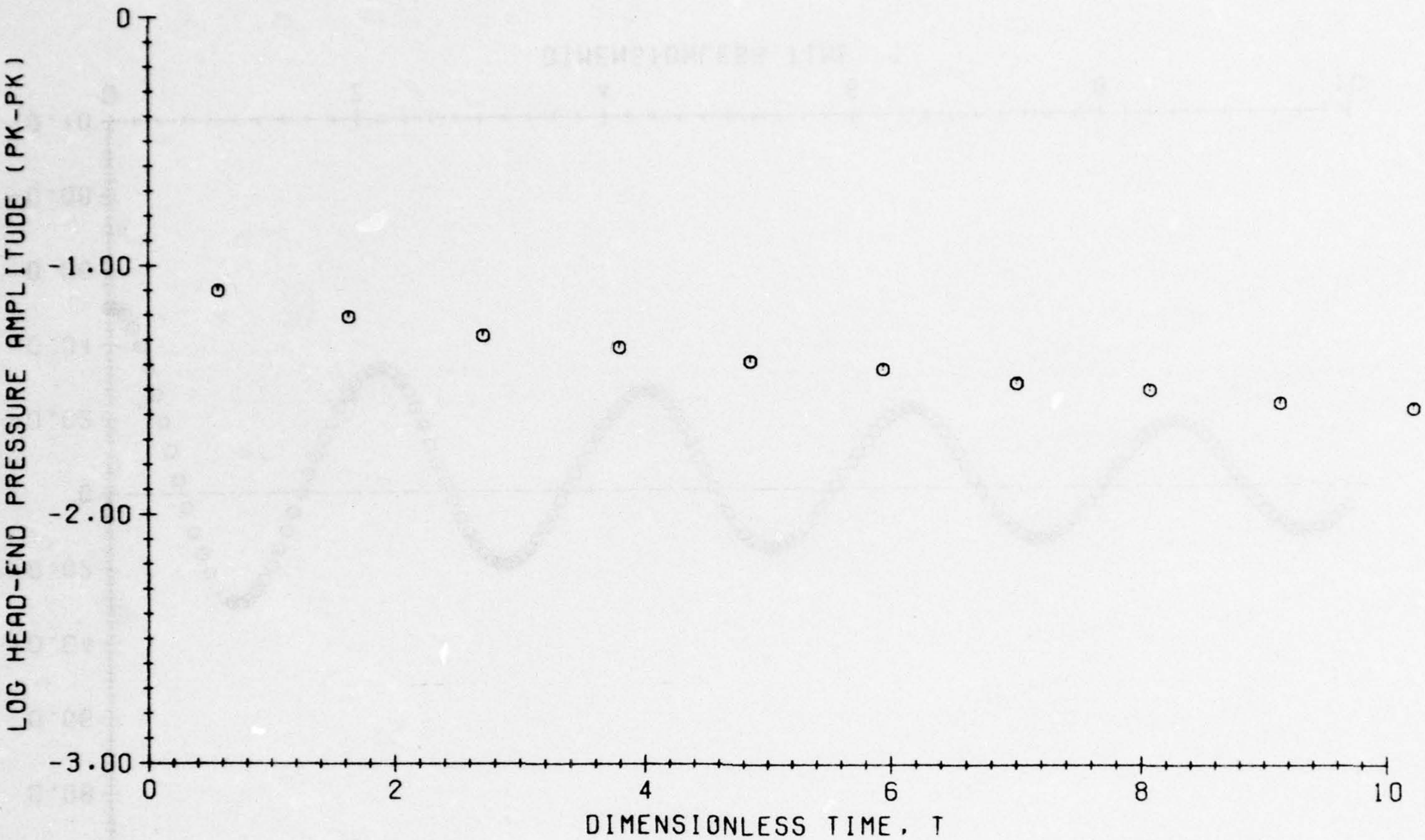
```
STEP( 400)  T=  3.603253  P(1)=107.677445  P(13)=107.390012  P(25)=106.569363  U(25)=  .267400  H(25)=  .078038  HG(1)=  -.017002
               12.351320          .009161          .006467          -.001224  U(13)=  .101914  UP(13)=  .114296  HG(25)=  .015816
```


HEAD-END PRESSURE PERTURBATION
0.10
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.10
0
2
4
6
8
10
DIMENSIONLESS TIME, T



MID-CHAMBER PRESSURE PERTURBATION
0.10
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.10
0
2
4
6
8
10
DIMENSIONLESS TIME, T


NOZZLE-END PRESSURE PERTURBATION
0.10
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.10
0
2
4
6
8
10
DIMENSIONLESS TIME, T


LOG HEAD-END PRESSURE AMPLITUDE (PK-PK)
0
-1.00
-2.00
-3.00
0
2
4
6
8
10
DIMENSIONLESS TIME, T

FORTRAN Source Code.

```
      PROGRAM MAIN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C
C     **** KZM VERSION 14JAN77 ****
C     **** INCLUDES PLOTTING ROUTINES ****
C
C     **** EXPLANATION OF INPUT ****
C
C     **** INPUTS IN MAIN PROGRAM ****
C     CARD 1
C      NOPT      =0  NO BURNING RESPONSE
C                =1  LINEAR BURNING RESPONSE
C                =2  NONLINEAR BURNING RESPONSE
C      NPRNT     =0    PRINT TIME HISTORIES AND PROFILES
C                =1  TIME HISTORIES AND PROFILES NOT PRINTED
C       **** INPUTS IN SUBROUTINE INPUT ****
C     CARD 1
C     HEADER          ALPHANUMERIC HEADING
C     CARD 2
C     PIN       =   INITIAL CHAMBER PRESSURE (ATMOSPHERES)
C     TFSTR     =   ADIABATIC FLAME TEMPERATURE (DEG R )
C     CARD 3
C     ELSTR = CHAMBER LENGTH (FT)
C     RCHSTR = CHAMBER RADIUS (FT)
C     UT      = MACH NUMBER AT NOZZLE ENTRANCE
C     CARD 4
C     PRSTR = REFERENCE PRESSURE IN PSI
C     TRSTR = REFERENCE TEMPERATURE IN DEG R
C     RGAS = GAS CONSTANT  (FT-LBF)/(LBM-R)
C     GAM = SPECIFIC HEAT RATIO
C     CARD 5
C     SIGMA = PARTICLE DIAMETER (MICRONS)
C     SMDPC = RATIO OF PARTICLE MASS FLUX TO GAS MASS FLUX
C     NLDG  = 0   LINEAR DRAG LAW
C           = 1   NONLINEAR DRAG LAW
C     CARD 6
C     RHSSTR= RHO OF THE SOLID IN LBM/FT**3
C     CSTR= SPECIFIC HEAT OF THE SOLID IN BTU/(LBM-R)
C     SKSSTR= CONDUCTIVITY OF THE SOLID IN BTU/(FT-SEC-R)
C     AES= ACTIVATION ENERGY OF SURFACE REACTION IN CAL/MOLE
C     CARD 7
C     QWSTR= ENDOTHERMIC HEAT RELEASE AT THE SURFACE IN BTU/LBM
C     CARD 8
C     CPSTR= SPECIFIC HEAT OF THE GAS IN BTU/(LBM-R)
C     SKGSTR= CONDUCTIVITY OF THE GAS IN BTU/(FT-SEC-R)
C     AEG= ACTIVATION ENERGY OF THE GAS PHASE REACTION IN CAL/MOLE
C     CARD 9
C     TSSTRR= REFERENCE TEMPERATURE OF SURFACE IN DEG RANKINE
C     SRS = SURFACE REGRESSION RATE IN FT/SEC
C      NOTE-- 3.28E-02 FT/SEC = 1 CM/SEC
C      PSURS=PRESSURE(PSI) AT SURFACE WHEN TS=TSR AND RATE = SRS
C     CTS1 = INITIAL GUESS OF SURFACE TEMPERATURE
```

```
C      **** INPUTS IN SUBROUTINE START ****
C      CARD 1
C      NSHOCK    =0  DOES NOT TEST FOR SHOCKS
C                =1  TESTS FOR SHOCKS
C      ICTYPE    =1  KOOKERS CONTINUOUS DISTURBANCE
C                =2  INITIAL FIRST LONGITUDINAL MODE
C      ISEN      =0  ISOTHERMAL DISTURBANCE
C                =1  ISENTROPIC DISTURBANCE
C      AMPL      =   HALF-AMPLITUDE OF DISTURBANCE
C      CARD 2
C      NTIMES    =   NUMBER OF INTEGRATION TIME STEPS
C      CARD 3
C      HEADER    =   ALPHANUMERIC HEADING
C      **** INPUTS IN SUBROUTINE LOGIC ****
C           PLOTTING PARAMETERS
C      CARD 1
C      LPLOT     = 0  NO PLOTS PRODUCED
C                = 1  PLOTTED OUTPUT PRODUCED
C      NLAST     =   NUMBER OF AXIAL LOCATIONS PLOTTED
C      CARD 2        YMAX, DELY, NTICY
C      CARD 3        TMAX, DELT, NTICT
C      CARD 4        TMAX4, DELT4, NTICT4 (AMPLITUDE PLOT)
C
   10 FORMAT(2I5)
      READ(5,10)  NOPT, NPRNT
      CALL INPUT(NOPT,NT,T)
      CALL START(NOPT,NT,T,NPRNT)
      STOP
      END


      SUBROUTINE INPUT(NOPT,NT,T)
      COMMON/HEAD/ HEADER(7),LPRINT,NTIMES,NSHOCK,JPLOT,PIN
      COMMON/FIXPR/MTOTA(5),GAM,GM1,GM12,GM12G,G2,GGM1,DGK,DGKNL
      COMMON/TIMTRN/DT,DT22,DXA(5),XISW(5),IDDA(5),ACMB(5),ASMB(5),
     1 ASMC(5)
      COMMON/COMFIX/ HAF(200,5),SMDG(200,5),SMDP(200,5),XIFC,HAFC,SMDGC
     1 ,REACTN,SMDPC
      COMMON/NOZDAT/ELSTR,RCHSTR,UT
      COMMON/MSFSLD/ SMXBS(100),APLOC(100),FSMDG(100),DXSBS,NBS,APC(100)
      COMMON/TEMWAV/CT(101,20),CNU(101,20),SW(101,20),SV(101,20),RGR(20)
      COMMON/BRNCON/ DYA(3),NTY(3),ALFTA(3),TYLOC(50),YO,Z1,Z2P,WCON,
     1EORG,EORS,ETF,QMC,BRAY,JTOT,JTOTM1,ARSTR,RHRSTR,Z1T,TS
      DIMENSION SAVE(8)
    1 FORMAT(7A10)
    2 FORMAT(2X,I6,E14.8,I6)
    5 FORMAT(3F10.0)
    6 FORMAT(5F10.0)
    7 FORMAT(2F10.0,I5)
    8 FORMAT(/,/,/,30X,7A10)
    9 FORMAT(/,10X,9E13.5)
```

```
  200 FORMAT (1H1)
  201 FORMAT(8X,7E16.8)
  202 FORMAT(2X,22H**********************)
  203 FORMAT(/,*  ITSUB W.N.C.FOR THE INITIAL SURFACE TEMP(AFTER 150 ITE
     1RATIONS).  *,3E15.8)
  204 FORMAT(*  BIGK=*,E14.8,*   YHC=*,E14.8,*    BRAY=*,E14.8,*   BR=*,
     1E14.8,*   WCON=*,E14.8,*   WSTRR=*,E14.8)
  205 FORMAT(*  EORG=*,E14.8,*    EORS=*,E14.8,*    TF=*,E14.8,*    TS=*,
     1E14.8,*   ETF=*,E14.8)
  206 FORMAT(*  R=*,E14.8,*  ACON=*,E14.8,*  QMC=*,E14.8,*    Z1H=*,E14.8
     1,*  Z2PH=*,E14.8,*    WSTRS=*,E14.8)
  207 FORMAT(*  Z1=*,E14.8,*  Z2P=*,E14.8,*  DXSBS=*,E14.8,*  ARSTR=*,
     1E14.8,*  RHRSTR=*,E14.8)
  210 FORMAT(/,*  QFSTR(BTU/LBM)=*,E14.8,*   BASED ON (QWSTR,TCSSTR,CPST
     1R,CSTR,TF,TSR) OF*,/,2X,6E15.8)
  211 FORMAT(/30X,*INITIAL CHAMBER PRESSURE = *,F10.1/)
  212 FORMAT (40X,*CHAMBER LENGTH = *,F10.3/
     1          40X,*CHAMBER RADIUS = *,F10.6/
     2          30X,*NOZZLE ENTRANCE MACH NO. = *,F10.5/)
  213 FORMAT (34X,*SURFACE HEAT RELEASE = *,F10.1/)
  214 FORMAT (30X,*REF. SURFACE TEMPERATURE = *,F10.1/
     1          26X,*REF. SURFACE REGRESSION RATE = *,F10.5/
     2          33X,*REF. SURFACE PRESSURE = *,F10.1/)
  215 FORMAT (2X/10X,*LINEAR COMBUSTION PARAMETERS*,10X,
     1          4HA = ,F7.3,5X,4HB = ,F7.3//)
  216 FORMAT (37X,*PARTICLE DIAMETER = *,F10.2,* MICRONS*/
     1          41X,*DRAG CONSTANT = *,F10.3/
     2          36X,*N.L. DRAG CONSTANT = *,F10.3/
     3          45X,*SMDP/SMDG = *,F10.4/)
  217 FORMAT (1H1,3X,*SMB = *,F9.5,5X,*SMC = *,F9.5,
     1          5X,*CMB = *,F9.5///)
C
      READ(5,1)(HEADER(I),I=1,7)
      WRITE (6,200)
      WRITE(6,8)(HEADER(I),I=1,7)
      READ(5,5) PIN,TFSTR
      WRITE (6,211) PIN
      PI=3.141592654
      MTOTA(1)=25
      SMDGC=0.100000000
      READ (5,5) ELSTR,RCHSTR,UT
      WRITE (6,212) ELSTR,RCHSTR,UT
      DXA(1)=1.00/FLOAT(MTOTA(1)-1)
      SMB=-1.000000
      SMC = 0.0
      CMB=SMC-SMB
      KS=1
      ASMC(KS)=SMC
      ASMB(KS)=SMB
      ACMB(KS)=CMB
      READ (5,6) PRSTR,TRSTR,RGAS,GAM
      HAFC = TFSTR/TRSTR
      ARSTR=SQRT(GAM*RGAS*TRSTR*32.2)
      RHRSTR=(PRSTR*144.00)/(RGAS*TRSTR)
```

```
C
      READ (5,7) SIGMA, SMDPC, NLDG
      SIG = SIGMA * 1.0E-06
      RMU = (8.834E-05)*(TFSTR/6273.0)**0.66
      RHOM = 4000
      DGK = 18.0*RMU*ELSTR/(RHOM*SIG*SIG*ARSTR)
      IF (NLDG .EQ. 0) GO TO 10
      DGKNL = 0.4797 * (RHRSTR*ARSTR*SIG/RMU)**0.66667
      GO TO 15
   10 DGKNL = 0.0
C
C          **********  UNSTABLE FORMULATION  **********
C
C       ***  PROPELLANT CONSTANTS  ***
   15 READ (5,6) RHSSTR,CSTR,SKSSTR,AES
      SKSSTR = SKSSTR * 1.0E-05
C     EORS= AES/(R*TCS) ASSUMING R=1.987 CAL/MOLE-K AND TCS=300-K
      EORS=AES/(1.987*300.00)
C     QWSTR= ENDOTHERMIC HEAT RELEASE AT THE SURFACE IN BTU/LBM
      READ (5,5) QWSTR
      WRITE (6,213) QWSTR
C     TCSSTR= TEMPERATURE OF THE COLD SOLID PROPELLANT IN DEG RANKINE
      TCSSTR = TRSTR
C          ***  PROPERTIES OF THE GAS PHASE FLAME  ***
      READ (5,6) CPSTR,SKGSTR,AEG
      SKGSTR = SKGSTR * 1.0E-05
C     EORG= AEG/(R*TCS) ASSUMING R=1.987 CAL MOLE-K AND TCS=300-K
      EORG=AEG/(1.987*300.00)
      TF=TFSTR/TCSSTR
      ETF=EXP(-EORG/TF)
C
C       *** REFERENCE STATE AT WHICH CONSTANTS ARE EVALUATED ***
C
C     TSSTRR= REFERENCE TEMPERATURE OF SURFACE IN DEG RANKINE
C      ASSUME SURFACE REGRESSION RATE IS SRS IN FT/SEC
C      NOTE-- 3.28E-02 FT/SEC = 1 CM/SEC
C     PSURS=PRESSURE(PSI) AT SURFACE WHEN TS=TSR AND RATE = SRS
      READ (5,6) TSSTRR,SRS,PSURS,CTS1
      TSR=TSSTRR/TCSSTR
      EXS=EXP(-EORS/TSR)
C      NOTE--   SRS=BR*EXP(-EORS/TSR)
      BR=SRS/EXS
      PSUR=PSURS/PRSTR
      WRITE (6,214) TSSTRR, SRS, PSURS
      WRITE (6,216) SIGMA, DGK, DGKNL, SMDPC
C      *** EVALUATION OF CONSTANTS ***
      BIGK=SKSSTR/(RHSSTR*CSTR*ARSTR*ELSTR)
      YHC=SQRT(BIGK)
      BRAY=BR/(ARSTR*YHC)
C     QFSTR= EXOTHERMIC HEAT RELEASE IN GAS PHASE REACTION IN BTU/LBM
      QFSTR=QWSTR+TCSSTR*(CPSTR*(TF-TSR)+CSTR*(TSR-1.00))
      Z1H=QWSTR/(CSTR*TCSSTR)
      Z2PH=(SKGSTR/SKSSTR)*(QFSTR/(CPSTR*TCSSTR))*(ELSTR/(RHSSTR*ARSTR))
```

```
      Z1=Z1H*BRAY
      Z1T = (CPSTR/CSTR - 1.0) * BRAY
      Z2P=Z2PH/BRAY
      QMC=(RHSSTR*YHC)/RHRSTR
C      *** SOLUTION FOR WCON BASED ON GIVEN VALUES OF PSUR AND TSR ***
      SRR=SRS/(YHC*ARSTR)
      ACONR=TSR-1.00
      TYM=ACONR*SRR
      WSTRR=(TYM+Z1H*SRR)*(SRR/Z2PH)
      WCON=WSTRR/(PSUR*PSUR*ETF)
C
C      *** ITERATIVE SOLUTION FOR A  TS  COMPATIBLE WITH INITIAL
C      ***  PRESSURE
C
      WSTRS=WCON*PIN*PIN*ETF
      Z2=Z2P*WSTRS
      CTS = CTS1
      SAVE(1)=1.00
      SAVE(2)=0.01*CTS
   20 EETS=EXP(EORS/CTS)
      GH=-(Z1/EETS) + Z2*EETS
      CAPF=(CTS-1.00)*BRAY/EETS - GH
      CALL ITSUB(CAPF,CTS,SAVE,0.000001,150)
      KBR=SAVE(1)
      GO TO (20,20,20,20,22,21), KBR
   21 WRITE(6,203) CTS,GH,CAPF
   22 TS=CTS
      ACON=TS-1.00
      R=BRAY*EXP(-EORS/TS)
      YO=+7.000
      NBS=11
      DXSBS=ELSTR/FLOAT(NBS-1)
      WRITE(6,210) QFSTR,QWSTR,TCSSTR,CPSTR,CSTR,TF,TSR
      WRITE(6,204) BIGK,YHC,BRAY,BR,WCON,WSTRR
      WRITE(6,205) EORG,EORS,TF,TS,ETF
      WRITE(6,206) R,ACON,QMC,Z1H,Z2PH,WSTRS
      WRITE(6,207) Z1,Z2P,DXSBS,ARSTR,RHRSTR
      DYA(1)=0.50
      DYA(2)=0.20
      DYA(3)=0.10
      NTY(1)=8
      NTY(2)=10
      NTY(3)=10
      JTOT=NTY(1)+NTY(2)+NTY(3)+1
      JTOTM1=JTOT-1
      TYLOC(1)=-YO
      NF=1
      DO 46 I=1,3
      NI=NF+1
      NF=NF+NTY(I)
      DY=DYA(I)
```

```
      DO 45 J=NI,NF
      TYLOC(J)=TYLOC(J-1)+DY
   45 CONTINUE
   46 CONTINUE
      IF (UT .LE. 0.0) R = 0.0
      DO 30 IBS=1,NBS
      SMXBS(IBS)=-1.00+FLOAT(IBS-1)*(DXSBS/ELSTR)
      APLOC(IBS)=PIN
      RGR(IBS)=R
      FSMDG(IBS)=R*QMC
      DO 25 J=1,JTOT
      Y=TYLOC(J)
      CT(J,IBS)=ACON*EXP(R*Y) +1.000
   25 CONTINUE
   30 CONTINUE
      G2=2.00*GAM
      GM1=GAM-1.000
      GM12=GM1/2.00
      GM12G=GM1/(2.00*GAM)
      GGM1=GAM*GM1
C
C     COMPUTE LINEAR COMBUSTION PARAMETERS A, B, AND N.
      IF (NOPT .NE. 1) GO TO 160
      E = EORS/TS
      A = E * (TS - 1.0)/TS
      RSTR = R * ARSTR * YHC
      RMSTR = RHSSTR * RSTR
      RMCP = RMSTR * CPSTR
      SQLAM = QFSTR*SKGSTR*WSTRS/(RMCP*RMCP*TS*TCSSTR)
      ELLCC = (E * SQLAM + 1.0) * CPSTR/CSTR
      EQCT = E * QWSTR/(CSTR*TS*TCSSTR)
      B = (A + ELLCC + EQCT)/A
      WRITE (6,215) A, B
C
  160 LPRINT=0
      WRITE(6,217) ASMB(1),ASMC(1),ACMB(1)
      IDDA(1)=0
      XISW(1)=ASMC(1)
      RETURN
      END


      SUBROUTINE START(NOPT,NT,T,NPRNT)
C
      COMMON/HEAD/ HEADER(7),LPRINT,NTIMES,NSHOCK,JPLOT,PIN
      COMMON/FIXPR/MTOTA(5),GAM,GM1,GM12,GM12G,G2,GGM1,DGK,DGKNL
      COMMON/TIMTRN/DT,DT22,DXA(5),XISW(5),IDDA(5),ACMB(5),ASMB(5),
     1 ASMC(5)
      COMMON/SPCTRN/ CAPX(200,5),XI(200,5),SMX(200,5),
     1 RW2(200,5),DLNA(200,5)
      COMMON/COMFIX/ HAF(200,5),SMDG(200,5),SMDP(200,5),XIFC,HAFC,SMDGC
     1 ,REACTN,SMDPC
      COMMON/VARG/R(200,5),RP(200,5),U(200,5),UP(200,5),S(200,5)
```

```
     1,P(200,5),SSP(200,5)
      COMMON/NOZDAT/ELSTR,RCHSTR,UT
      COMMON/MSFSLD/ SMXBS(100),APLOC(100),FSMDG(100),DXSBS,NBS,APC(100)
      COMMON/TEMWAV/CT(101,20),CNU(101,20),SW(101,20),SV(101,20),HGR(20)
      COMMON/BRNCON/ DYA(3),NTY(3),ALFTA(3),TYLOC(50),YO,Z1,Z2P,WCON,
     1EORG,EORS,ETF,QMC,BRAY,JTOT,JTOTM1,ARSTR,RHRSTR,Z1T,TS
      COMMON/NOZADM/ UBAR,PBAR,ADM
      COMMON/SSVAL/ RBAR(20),CTBAR(101,20),CTYBAR(101,20),
     1              Z2RP(20),ETGH(20),ERTS(20)
      COMMON/PLTVAR/ TCONV,P11,TPLOT(1000),YPLOT(3,1000),SMDG11
C
      DIMENSION  AREA(100),SAVE(8)
C
    1 FORMAT(7A10)
  100 FORMAT(2X,I3,10E12.5)
  101 FORMAT(4X,*M*,5X,*CAP X*,8X,*XI*,9X,*X STR*,
     1 9X,*RWALL*,6X,*DRWDX*,8X,*AREA*,7X,*DLNADX*,7X,*RW2*)
  102 FORMAT(1H1,3X,*M*,4X,*SMDG*,8X,*SMDP*,8X,*HAF*)
  103 FORMAT(/,/,/,*   THE FOLLOWING FLOW FIELD WAS READ IN ON CARDS FRO
     1M A PREVIOUS COMPUTATION*)
  105 FORMAT(2X,5E14.8)
  107 FORMAT(2X//*              UBAR = *,F9.6,*      PBAR = *,F9.4,
     1         *     ADM = *,F9.6,*     TCONV = *,F9.6//
     2         2X,*         THE RESTARTED FLOW FIELD CONTAINING*,
     3         * THE ADDED DISTURBANCE FOLLOWS      *)
  108 FORMAT(2X,* ITSUB IN START W.N.C..(WLAST,WCHOK,UT,RHON,ARL) ARE*,/
     16E14.8)
  109 FORMAT (3I5,F10.0)
  110 FORMAT (2X//9X,*MASS BALANCE (LBM/SEC):*,10X,
     1          *MASS IN = *,F9.4,5X,*MASS OUT = *,F9.4/)
  111 FORMAT (9X,*OMEGA = *,F7.4/)
C
      NT = 0
      T = 0.0
      PI=3.1415927
      KS=1
      KST=1
      MTOT=MTOTA(KS)
      CMB=ACMB(KS)
      SMB=ASMB(KS)
      DX=DXA(KS)
      IDDA(1)=0
      XISW(1)=ASMC(1)
      CX=0.00
      WRITE(6,101)
      RW = RCHSTR
      DRWDX = 0.0
      AW = PI*RW*RW
      DO 10 I=1,MTOT
      CAPX(I,KS)=CX
      XI(I,KS)=CMB*CX+SMB
      SMX(I,KS)=XI(I,KS)
      SMXI = SMX(I,KS)
```

```
      DLNA(I,KS) = 0.0
      RW2(I,KS) = 2.0*ELSTR/RW
      AREA(I)=AW
      SMXP=SMXI*ELSTR
      WRITE(6,100) I,CX,XI(I,KS),SMXP,RW,DRWDX,AW,
     1 DLNA(I,KS),RW2(I,KS)
      CALL COMBNT(SMXI,KS,KST,HAF(I,KS),SMDG(I,KS),SMDP(I,KS))
      CX=DX*FLOAT(I)
   10 CONTINUE
      WRITE(6,102)
      DO 15 M=1,MTOT
      WRITE(6,100) M,SMDG(M,KS),SMDP(M,KS),HAF(M,KS)
   15 CONTINUE
      HIN = HAFC
      RIN=PIN/HIN
      SIN=ALOG(PIN)-GAM*ALOG(RIN)
      AINT=SQRT(PIN/RIN)
      UIN = UT*AINT
      OOG = 1.00/GAM
      DLO = SMX(1,KS)
      DDL = SMX(MTOT,KS) - DLO
      DUDX = UIN/DDL
      CPART = 1.0 + SQRT(1.0 + 8.0*DUDX/DGK)
      DO 40 M = 1,MTOT
      R(M,KS) = RIN
      P(M,KS) = PIN
      S(M,KS) = SIN
      SSP(M,KS) = AINT
      U(M,KS) = (SMX(M,KS) - DLO) * DUDX
      UP(M,KS) = 2.0*U(M,KS)/CPART
      RP(M,KS) = 0.5*SMDPC*CPART*R(M,KS)
   40 CONTINUE
      LPRINT=0
      READ (5,109) NSHOCK,ICTYPE,ISEN,AMPL
      READ (5,109) NTIMES
      P11 = P(1,1)
      SMDG11 = SMDG(1,1)
      UBAR = U(MTOT,1)
      PBAR = P(MTOT,1)
      ADM = GM12G * UBAR/PBAR
      LPRINT=0
      JPLOT = 0
      TCONV = SSP(1,1)/(SMX(MTOT,1) - SMX(1,1))
      WRITE(6,103)
      DO 176 IBS = 1,NBS
      APC(IBS) = APLOC(IBS)
  176 CONTINUE
      CALL OUTPUT(NT,T,KST,0)
      LPRINT = 0
C
C     CALCULATE MASS BALANCE
```

```
      SMOUT = R(MTOT,1)*RHRSTR*PI*RCHSTR*RCHSTR*U(MTOT,1)*ARSTR
      SUM = 0.0
      DO 173 M = 2,MTOT
      DELX = ELSTR*DX
      AVG = (SMDG(M,1) + SMDG(M-1,1))/2.0
      SUM = SUM + AVG*DELX
  173 CONTINUE
      SMIN = 2.0*PI*RCHSTR*RHRSTR*ARSTR*SUM
      WRITE (6,110) SMIN, SMOUT
C
      IF (RGR(1) .LE. 0.0) GO TO 169
      FREQ = PI * SSP(1,1)/(SMX(MTOT,1) - SMX(1,1))
      OMEGA = FREQ/(RGR(1)*RGR(1))
      WRITE (6,111) OMEGA
C
C     CALCULATE INITIAL DISTURBANCE
  169 AMDIST = AMPL * P(1,1)
      DLO = SMX(1,1)
      IF (ICTYPE.EQ.2) GO TO 174
      AMSTRT = AMDIST
      MSTOP = 9
      DDL = SMX(9,1) - DLO
      GO TO 175
  174 AMSTRT = 0.0
      MSTOP = MTOT
      DDL = SMX(MTOT,1) - DLO
  175 DO 180 M = 1,MSTOP
      PINC = AMSTRT + AMDIST*COS(PI*(SMX(M,1)-DLO)/DDL)
      IF (ISEN.EQ.1) GO TO 177
      TLOCL = P(M,1)/R(M,1)
      P(M,1) = P(M,1) + PINC
      R(M,1) = P(M,1)/TLOCL
      S(M,1) = ALOG(P(M,1)) - GAM*ALOG(R(M,1))
      GO TO 179
  177 P(M,1) = P(M,1) + PINC
      R(M,1) = (P(M,1)/EXP(S(M,1)))**OOG
  179 SSP(M,1) = SQRT(P(M,1)/R(M,1))
  180 CONTINUE
      READ(5,1)(HEADER(KK),KK=1,7)
      WRITE(6,107) UBAR, PBAR, ADM, TCONV
      NT=0
      T=0.00
C
      IF (NOPT.NE.1) GO TO 200
      DO 185 N = 1,NBS
      DO 185 J = 1,JTOT
      CTBAR(J,N) = CT(J,N)
      CTYBAR(J,N) = (CT(J,N) - 1.0) * RGR(N)
  185 CONTINUE
C
  200 CALL NUTEMP(KST,NOPT,NT)
      JPLOT = 0
      CALL OUTPUT(NT,T,KST,0)
      CALL LOGIC(KST,NOPT,NPRNT)
      RETURN
      END
```

```
      SUBROUTINE OUTPUT(NT, T, KST, NPRNT)
C
      COMMON/HEAD/ HEADER(7),LPRINT,NTIMES,NSHOCK,JPLOT, PIN
      COMMON/VARG/R(200, 5), RP(200, 5), U(200, 5), UP(200, 5), S(200, 5)
     1, P(200, 5), SSP(200, 5)
      COMMON/FIXPR/MTOTA(5), GAM, GM1, GM12, GM12G, G2, GGM1, DGK, DGKNL
      COMMON/TIMTRN/DT, DT22, DXA(5), XISW(5), IDDA(5), ACMB(5), ASMB(5),
     1 ASMC(5)
      COMMON/SPCTRN/ CAPX(200, 5), XI(200, 5), SMX(200, 5),
     1 RW2(200, 5), DLNA(200, 5)
      COMMON/COMFIX/ HAF(200, 5), SMDG(200, 5), SMDP(200, 5), XIFC, HAFC, SMDGC
     1 , REACTN, SMDPC
      COMMON/NOZDAT/ELSTR, RCHSTR, UT
      COMMON/MSFSLD/ SMXBS(100), APLOC(100), FSMDG(100), DXSBS, NBS, APC(100)
      COMMON/TEMWAV/CT(101, 20), CNU(101, 20), SW(101, 20), SV(101, 20), RGR(20)
      COMMON/BRNCON/ DYA(3), NTY(3), ALFTA(3), TYLOC(50), YO, Z1, Z2P, WCON,
     1EORG, EORS, ETF, QMC, BRAY, JTOT, JTOTM1, ARSTR, RHRSTR, Z1T, TS
      COMMON/DDMG/ SMDDG(200, 5)
      COMMON/NOZADM/ UBAR, PBAR, ADM
      COMMON/PLTVAR/ TCONV, P11, TPLOT(1000), YPLOT(3, 1000), SMDG11
C
    1 FORMAT(1H1, 25X, 7A10)
    2 FORMAT(/, 15X, *COMPUTATION STEP(*, I5, *)  WHERE TIME(NON-DIMENSIONAL
     1)=*, E11.4, *   DT=*, E11.4, *    T(MIL-SEC)=*, E11.4)
    3 FORMAT(   7X, *INDEX M*, 6X, *X STR*, 8X, *MACH NO.*, 5X, *PRESSURE*, 5X,
     1*DENSITY*, 6X, *VELOCITY*, 5X, *ENTROPY*, 6X, *ENTHALPY*, 5X, *A(LOC)*)
    4 FORMAT(7X, I4, 4X, 8E13.6)
    5 FORMAT(/, /, 9X, *REGION(*, I2, *)       WHERE SMB=*,
     1     E12.5, *   SMC=*, E12.5, *   CMB=*, E12.5, /)
    6 FORMAT (/, 32X, *PARTICLE*, 5X, *PARTICLE*/7X, *INDEX M*,
     1  6X, *X STR*, 8X, *DENSITY*, 5X, *VELOCITY*, 6X, *SMDG*, 9X,
     2  *SMDP*, 8X, *SMDDG*)
    7 FORMAT(/, 9X, *INDEX OF DISCONTINUITY DIRECTION=*, I3,
     1  *          AND DISCONTINUITY LOCATION=*, E12.5, /)
    8 FORMAT(/, 8X, *IBS*, 9X, *XSTRBS*, 7X, *F SMDG*, 7X,
     1*R*, 11X, *TEMP SUR.*, 5X, *PRESS(LOC)*)
    9 FORMAT(2X, *STEP(*, I4, *)   T=*, F10.6, *   P(1)=*, F10.6, *   P(*, I2, *)=*
     1, F10.6, *   P(*, I2, *)=*, F10.6, *   U(*, I2, *)=*, F10.6,
     2 *    M(*, I2, *)=*, F10.6, *    MG(1)=*, F10.6)
   10 FORMAT(16X, F10.6, 7X, F10.6, 8X, F10.6, 8X, F10.6, *   U(*, I2, *)=*, F10.6,
     1         *   UP(*, I2, *)=*, F10.6, *   MG(*, I2, *)=*, F10.6)
C
      LPRINT=LPRINT+1
      IF(LPRINT.LT.0) GO TO 200
      LPRINT=-100
      IF (NPRNT .GT. 0) GO TO 200
      TELSTR=2.00*ELSTR
      TACT=T*(ELSTR/ARSTR)*1000.000
      WRITE(6, 1)(HEADER(JJ), JJ=1, 7)
      WRITE(6, 2) NT, T, DT, TACT
```

```
      DO 100 KS=1,KST
      SMB=ASMB(KS)
      CMB=ACMB(KS)
      SMC=ASMC(KS)
      WRITE(6,5) KS,SMB,SMC,CMB
      WRITE(6,3)
      MTOT=MTOTA(KS)
      MID = (MTOT + 1)/2
      DO 50 M=1,MTOT
      RHOG=R(M,KS)
      SG=S(M,KS)
      PG=P(M,KS)
      UG=U(M,KS)
      HLOC=PG/RHOG
      ALOC=SSP(M,KS)
      EMACH=UG/ALOC
      SMXSTR=SMX(M,KS)*ELSTR
      RWALL=TELSTR/RW2(M,KS)
      WRITE(6,4) M,SMXSTR,EMACH,PG,RHOG,UG,SG,HLOC,ALOC
   50 CONTINUE
      WRITE(6,7) IDDA(KS),XISW(KS)
      WRITE(6,6)
      DO 60 M=1,MTOT
      SMXSTR = SMX(M,KS)*ELSTR
      WRITE(6,4) M,SMXSTR,RP(M,KS),UP(M,KS),SMDG(M,KS),
     1          SMDP(M,KS),SMDDG(M,KS)
   60 CONTINUE
      WRITE(6,8)
      DO 150 IBS=1,NBS
      SMXBSS=SMXBS(IBS)*ELSTR
      WRITE(6,4) IBS,SMXBSS,FSMDG(IBS),RGR(IBS),CT(JTOT,IBS),APLOC(IBS)
  150 CONTINUE
  100 CONTINUE
  200 NTR = (NT/2) * 2
      IF (NT .NE. NTR) GO TO 210
      EMACH = U(MTOT,1)/SSP(MTOT,1)
      IF (SMDG11 .LE. 0.0) GO TO 204
      YSMDG = (SMDG(1,1) - SMDG11)/SMDG11
      YSMDGN = (SMDG(MTOT,1) - SMDG11)/SMDG11
      GO TO 206
  204 YSMDG = 0.0
      YSMDGN = 0.0
  206 IF (NPRNT .GT. 0) GO TO 207
      WRITE(6,9) NT,T,P(1,1),MID,P(MID,1),MTOT,P(MTOT,1),
     1          MTOT,U(MTOT,1),MTOT,EMACH,YSMDG
  207 JPLOT = JPLOT + 1
      TPLOT(JPLOT) = TCONV * T
      YPLOT(1,JPLOT) = (P(1,1) - P11)/P11
      YPLOT(2,JPLOT) = (P(MID,1) - P11)/P11
      YPLOT(3,JPLOT) = (P(MTOT,1) - P11)/P11
      IF (NPRNT .GT. 0) GO TO 210
      WRITE (6,10) TPLOT(JPLOT), (YPLOT(KK,JPLOT), KK = 1,3),
     1          MID,U(MID,1),MID,UP(MID,1),MTOT,YSMDGN
  210 RETURN
      END
```

```
      SUBROUTINE LOGIC(KST,NOPT,NPRNT)
C
      COMMON/HEAD/ HEADER(7),LPRINT,NTIMES,NSHOCK,JPLOT,PIN
      COMMON/FIXPR/MTOTA(5),GAM,GM1,GM12,GM12G,G2,GGM1,DGK,DGKNL
      COMMON/TIMTRN/DT,DT22,DXA(5),XISW(5),IDDA(5),ACMB(5),ASMB(5),
     1 ASMC(5)
      COMMON/SPCTRN/ CAPX(200,5),XI(200,5),SMX(200,5),
     1 RW2(200,5),DLNA(200,5)
      COMMON/COMFIX/ HAF(200,5),SMDG(200,5),SMDP(200,5),XIFC,HAFC,SMDGC
     1 ,REACTN,SMDPC
      COMMON/VARG/R(200,5),RP(200,5),U(200,5),UP(200,5),S(200,5)
     1,P(200,5),SSP(200,5)
      COMMON/TEMWAV/CT(101,20),CNU(101,20),SW(101,20),SV(101,20),RGR(20)
      COMMON/NOZDAT/ELSTR,RCHSTR,UT
      COMMON/MSFSLD/ SMXBS(100),APLOC(100),FSMDG(100),DXSBS,NBS,APC(100)
      COMMON/BRNCON/ DYA(3),NTY(3),ALFTA(3),TYLOC(50),YO,Z1,Z2P,WCON,
     1EORG,EORS,ETF,QMC,BRAY,JTOT,JTOTM1,ARSTR,RHRSTR,Z1T,TS
      COMMON/DDMG/ SMDDG(200,5)
      COMMON/VARUPD/ RUD(2,5),UUD(2,5),SUD(2,5),PUD(2,5),SSPUD(2,5),
     1               RPUD(2,5),UPUD(2,5)
      COMMON/SSVAL/ RBAR(20),CTBAR(101,20),CTYBAR(101,20),
     1              Z2RP(20),ETGH(20),ERTS(20)
      COMMON/PLTVAR/ TCONV,P11,TPLOT(1000),YPLOT(3,1000),SMDG11
C
      DIMENSION  IBUF(512),ITT(3),ITY1(3),ITY2(4),ITY3(4),ITY4(4),
     1           DUMMYT(500),DUMMYY(500),PRS(3),TIME(3),
     2           PMAX(100),TIMAX(100),PKPK(100),TMEAN(100)
C
    2 FORMAT(2X,3I10,2E15.8)
    3 FORMAT(2X,5E15.8)
  202 FORMAT(/,*      CMB FOR REGION KS=*,I2,* IS =*,E14.6,5X,*(NT=*,I8,*
     1  WHERE T=*,E14.6,*)*)
  203 FORMAT(*    THE LAST REGION(KS=*,I2,*) IS BEING DELETED*)
  204 FORMAT(*    THE SHOCK WAVE IS TO BE REFLECTED ON THIS STEP*)
  205 FORMAT(//,*         IN REGION(KS=*,I2,*) SHDET WAS FOUND TO BE=*,E14.
     18,* FOR JS=*,I3,*  WITH DIRECTION=*,I3,*   (NT=*,I8,* WHERE T=*,E1
     24.6,*)*)
  206 FORMAT(/,/,*    THE SHOCK WAVE WAS FOUND TO EXIST IN THE FOLLOWING
     1FLOW FIELD*)
  207 FORMAT(/,/,*    THE NEW FLOW FIELD REGIONS APPEAR AS FOLLOWS    (NO
     1TE.. THE ADVANCE AT THIS TIME STEP IS NOT YET COMPLETE)*)
  208 FORMAT(/,/,*          THIS FLOW FIELD APPEARS AS FOLLOWS        *)
  210 FORMAT(2X/2X,*NPMAX = *,I3,5X,*TMAX = *,F8.4,5X,
     1      *PMAX = *,F8.5,5X,*PK-PK AMPLITUDE = *,F8.5,
     2      * AT T = *,F8.4,5X,*PMEAN = *,F8.5)
  500 FORMAT(/,/,*          IN LOGIC(NT=*,I6,* AT T=*,E14.8,*)  THE REGION(K
     1S=*,I2,*) WHERE CMB=*,E14.8,* HAS FAILED THE CRITERIA FOR A SMALL
     2SECTION*)
  501 FORMAT(2F10.0,I5)
  502 FORMAT(2I5)
  503 FORMAT (2X/2X,*NEGATIVE REGRESSION RATE AT M = *,I2)
C
```

```
      DATA   ITT/21HDIMENSIONLESS TIME, T/,
     1       ITY1/30HHEAD-END PRESSURE PERTURBATION/,
     2       ITY2/33HMID-CHAMBER PRESSURE PERTURBATION/,
     3       ITY3/32HNOZZLE-END PRESSURE PERTURBATION/,
     4       ITY4/39HLOG HEAD-END PRESSURE AMPLITUDE (PK-PK)/
C
      READ (5,502) LPLOT,NLAST
      IF (LPLOT .EQ. 0)  GO TO 6
      READ (5,501) YMAX,DELY,NTICY
      READ (5,501) TMAX,DELT,NTICT
      READ(5,501) TMAX4,DELT4,NTICT4
      YMIN = -YMAX
      TMIN = 0.0
    6 KI = 1
      LCHEK=0
      DXMIN = 1.00
      DO 5 KS = 1,KST
      SMX1 = SMX(1,KS)
      SMX2 = SMX(2,KS)
      DXTR = SMX2 - SMX1
      IF (DXTR .LT. DXMIN) DXMIN = DXTR
    5 CONTINUE
      IF (NOPT.NE.1) GO TO 8
      DO 7 IBS = 1,NBS
      RBAR(IBS) = RGR(IBS)
      Z2PH = Z2P*BRAY
      PC = APC(IBS)
      Z2BAR = Z2PH*WCON*ETF*PC*PC
      Z2RP(IBS) = 2.0*Z2BAR/(RBAR(IBS)*PC)
      Z1H = Z1/BRAY
      GHBAR = Z1H*RBAR(IBS) + Z2BAR/RBAR(IBS)
      CTS = CT(JTOT,IBS)
      ETT = EORS/(CTS*CTS)
      ETGH(IBS) = GHBAR*ETT + Z1T*RBAR(IBS)/BRAY
      ERTS(IBS) = RBAR(IBS)*ETT
    7 CONTINUE
    8 NPMAX = 1
      PMAX(1) = (P(1,1) - P11)/P11
      TIMAX(1) = 0.0
      PMEAN = 0.0
      DO 200 NT=1,NTIMES
      AMAX=1.00
      UMAX = 0.0
      DO 15 KS=1,KST
      MTOT=MTOTA(KS)
      DO 10 M=1,MTOT
      UT1 = ABS(U(M,KS))
      APOS = SSP(M,KS)
      IF (UT1 .GT. UMAX) UMAX = UT1
      IF (APOS .GT. AMAX) AMAX = APOS
   10 CONTINUE
   15 CONTINUE
```

```
   20 DT=0.800*DXMIN/(UMAX + AMAX)
      DT22=DT*DT/2.00
      TWDT=2.00*DT
      ALFTA(1)=DYA(1)/TWDT
      ALFTA(2)=DYA(2)/TWDT
      ALFTA(3)=DYA(3)/TWDT
C
C     **** CALCULATE PRESSURE MAXIMA AND MINIMA ****
      IF (NT .GT. 3) GO TO 30
      PRS(NT) = (P(1,1) - P11)/P11
      TIME(NT) = T * TCONV
      GO TO 35
   30 PRS(1) = PRS(2)
      PRS(2) = PRS(3)
      PRS(3) = (P(1,1) - P11)/P11
      TIME(1) = TIME(2)
      TIME(2) = TIME(3)
      TIME(3) = T * TCONV
   35 IF (NT .LT. 3) GO TO 40
      DPL = PRS(3) - PRS(2)
      DPS = PRS(2) - PRS(1)
      IF (DPL*DPS) 45, 45, 40
   45 DPMX1 = PMAX(NPMAX) - PMEAN
      DPMX2 = PRS(2) - PMEAN
      IF (DPMX1*DPMX2) 46, 48, 48
   48 PMX1 = ABS(DPMX1)
      PMX2 = ABS(DPMX2)
      IF (PMX2 .GE. PMX1) GO TO 49
      GO TO 40
   46 IF (NPMAX .EQ. 1) GO TO 47
      SMALL = 0.5 * ABS(DPMX1)
      PMX2 = ABS(DPMX2)
      IF (PMX2 .LT. SMALL) GO TO 40
      PMX1 = PMAX(NPMAX-1)
      PMX2 = PMAX(NPMAX)
      PKPK(NPMAX) = ABS(PMX2 - PMX1)
      TMEAN(NPMAX) = (TIMAX(NPMAX-1) + TIMAX(NPMAX))/2.0
      PMEAN = (PMAX(NPMAX-1) + PMAX(NPMAX))/2.0
      WRITE(6,210) NPMAX,TIMAX(NPMAX),PMAX(NPMAX),PKPK(NPMAX),
     1             TMEAN(NPMAX),PMEAN
   47 NPMAX = NPMAX + 1
   49 PMAX(NPMAX) = PRS(2)
      TIMAX(NPMAX) = TIME(2)
   40 CONTINUE
C
      T=T+DT
C
C     **** TEST FOR SHOCK DEVELOPMENT ****
      IF (NSHOCK .EQ. 0) GO TO 101
      DO 100 KS=KI,KST
      Y1=P(1,KS)
      Y2=P(2,KS)
      Y3=P(3,KS)
      MTOT=MTOTA(KS)
      SHDETM=0.000
```

```
      DO 95 MO=4,MTOT
      Y4=P(MO,KS)
      CALL SHDETL(Y1,Y2,Y3,Y4,SHDET,NYES)
      IF(NYES.EQ.0) GO TO 92
      IF(SHDET .LT. SHDETM) GO TO 92
      SHDETM=SHDET
      MOH=MO
      Y1H=Y1
      Y4H=Y4
C
C
   92 Y1=Y2
      Y2=Y3
      Y3=Y4
   95 CONTINUE
      IF(NYES.EQ.0) GO TO 100
      INDD=-1
      IF(Y1H.GT.Y4H) INDD=+1
      JS=MOH-1
      IF(INDD.EQ.1) JS=MOH-2
      WRITE(6,205) KS,SHDETM,JS,INDD,NT,T
      WRITE(6,206)
      LPRINT=0
      CALL OUTPUT(NT,T,KST,NPRNT)
      LPRINT=0
C
      STOP
C
  100 CONTINUE
C
  101 CALL BNDMOC(KST,-1)
      IF (UT .GT. 0.0) GO TO 103
      CALL BNDMOC(KST,1)
      GO TO 104
  103 CALL NOZMOC(KST)
  104 DO 105 KS=1,KST
      CALL TAYLOR(KS)
  105 CONTINUE
      DO 106 KS = KI,KST
      MTOT = MTOTA(KS)
      U(1,KS) = UUD(1,KS)
      UP(1,KS) = UPUD(1,KS)
      P(1,KS) = PUD(1,KS)
      R(1,KS) = RUD(1,KS)
      RP(1,KS) = RPUD(1,KS)
      S(1,KS) = SUD(1,KS)
      SSP(1,KS) = SSPUD(1,KS)
      U(MTOT,KS) = UUD(2,KS)
      UP(MTOT,KS) = UPUD(2,KS)
      P(MTOT,KS) = PUD(2,KS)
      R(MTOT,KS) = RUD(2,KS)
      RP(MTOT,KS) = RPUD(2,KS)
      S(MTOT,KS) = SUD(2,KS)
      SSP(MTOT,KS) = SSPUD(2,KS)
  106 CONTINUE
  121 CONTINUE
```

```
      IF (NOPT.EQ.0) GO TO 198
  193 CALL NUTEMP(KST,NOPT,NT)
  194 DO 196 KS=1,KST
      MTOT=MTOTA(KS)
      DO 195 M=1,MTOT
      OSMDG=SMDG(M,KS)
      CALL COMBNT(SMX(M,KS),KS,KST,HAF(M,KS), SMDGN, SMDP(M,KS))
      SMDDG(M,KS)=(SMDGN-OSMDG)/DT
      SMDG(M,KS)=SMDGN
      IF (SMDGN .GE. 0.0) GO TO 195
      WRITE (6,503) M
      LPRINT = 0
      CALL OUTPUT(NT,T,KST,NPRNT)
      STOP
  195 CONTINUE
  196 CONTINUE
  198 CALL OUTPUT(NT,T,KST,NPRNT)
      IF (LPLOT .EQ. 0) GO TO 200
      T1 = TCONV * T
      IF ((T1.GT.TMAX) .OR. (JPLOT.GE.500)) GO TO 300
      GO TO 200
C
C     **** PLOTTED OUTPUT ****
C
  300 IF (NLAST .EQ. 0)  GO TO 330
      NUM = JPLOT
      DO 320 NPLOT = 1,NLAST
      JPLOT = 0
      DO 310 J = 1,NUM
      IF((YPLOT(NPLOT,J).LT.YMIN).OR.(YPLOT(NPLOT,J).GT.YMAX))
     1 GO TO 310
      JPLOT = JPLOT + 1
      DUMMYT(JPLOT) = TPLOT(J)
      DUMMYY(JPLOT) = YPLOT(NPLOT,J)
  310 CONTINUE
      IF (JPLOT .EQ. 0) GO TO 320
      GO TO (311,312,313), NPLOT
  311 CALL GRAPHS(IBUF,512,4,JPLOT,NTICT,NTICY,TMAX,YMAX,
     1      TMIN,YMIN,ITT,ITY1,21,30,DUMMYT,DUMMYY,DELT,DELY,
     2      HEADER)
      GO TO 320
  312 CALL GRAPHS(IBUF,512,4,JPLOT,NTICT,NTICY,TMAX,YMAX,
     1      TMIN,YMIN,ITT,ITY2,21,33,DUMMYT,DUMMYY,DELT,DELY,
     2      HEADER)
      GO TO 320
  313 CALL GRAPHS(IBUF,512,4,JPLOT,NTICT,NTICY,TMAX,YMAX,
     1      TMIN,YMIN,ITT,ITY3,21,32,DUMMYT,DUMMYY,DELT,DELY,
     2      HEADER)
  320 CONTINUE
C
  330 JPLOT = 0
      TMIN = TMAX
      TMAX = TMAX + 10.0
  200 CONTINUE
```

```
C
      IF (LPLOT.EQ.0) GO TO 400
      JPLOT = 0
      NPMAX = NPMAX - 1
      DO 350 J =1,NPMAX
      IF (PKPK(J) .LE. 0.0) GO TO 350
      PMXLG = ALOG10(PKPK(J))
      IF((PMXLG.LT.-3.0).OR.(PMXLG.GT.0.0)) GO TO 350
      JPLOT = JPLOT + 1
      DUMMYT(JPLOT) = TMEAN(J)
      DUMMYY(JPLOT) = PMXLG
  350 CONTINUE
      CALL GRAPHS(IBUF,512,4,JPLOT,NTICT4,31,TMAX4,0.0,0.0,-3.0,
     1            ITT,ITY4,21,39,DUMMYT,DUMMYY,DELT4,1.0,HEADER)
C
      IF (LPLOT .EQ. 1) CALL PLOT(0,0,999)
C
  400 RETURN
      END


      SUBROUTINE BNDMOC(KST,MBC)
C     ** THIS SUBROUTINE IS CORRECT FOR TWO PHASE FLOW -  THE
C     PARTICLE FLOW IS COMPUTED AND D(LN(AREA))/DX=0.0**
      COMMON/FIXPR/MTOTA(5),GAM,GM1,GM12,GM12G,G2,GGM1,DGK,DGKNL
      COMMON/TIMTRN/DT,DT22,DXA(5),XISW(5),IDDA(5),ACMB(5),ASMB(5),
     1 ASMC(5)
      COMMON/SPCTRN/ CAPX(200,5),XI(200,5),SMX(200,5),
     1 RW2(200,5),DLNA(200,5)
      COMMON/COMFIX/ HAF(200,5),SMDG(200,5),SMDP(200,5),XIFC,HAFC,SMDGC
     1 ,REACTN,SMDPC
      COMMON/VARG/R(200,5),RP(200,5),U(200,5),UP(200,5),S(200,5)
     1,P(200,5),SSP(200,5)
      COMMON/VARUPD/ RUD(2,5),UUD(2,5),SUD(2,5),PUD(2,5),SSPUD(2,5),
     1              RPUD(2,5),UPUD(2,5)
  200 FORMAT(/,*  ERROR IN BNDMOC   *,I4,4E14.8)
C
C     ***STREAMLINED (1AUG72) VERSION OF BNDMOC***
C     *** MBC = -1    LEFT-HAND BOUNDARY ***
C     *** MBC =  1    RIGHT-HAND BOUNDARY ***
C
      CMB=ACMB(1)
      SMB=ASMB(1)
      RMBC = MBC
      DX=DXA(1)
      IF (MBC .EQ. 1) GO TO 5
      M1 = 1
      M2 = 2
      M3 = 3
      MM = 1
      GO TO 8
```

```
  5 MTOT = MTOTA(1)
    M1 = MTOT
    M2 = MTOT-1
    M3 = MTOT-2
    MM = 2
  8 R1=R(M1,1)
    S1=S(M1,1)
    P1=P(M1,1)
    P2OLD=P1
    RP1 = RP(M1,1)
    RP2 = RP1
    RW2F=RW2(M1,1)
    GMRF=GAM*SMDG(M1,1)*RW2F
    H1=P1/R1
    A1=SSP(M1,1)
    HAFF=HAF(M1,1)
    SINC1=GMRF*(HAFF-H1)/P1
    S2=S1+SINC1*DT
    CAPU2 = RMBC*A1/CMB
    DXO=RMBC*DT*CAPU2
    DXNO=DXO/DX
    UG2=U(M2,1)
    UG3=U(M3,1)
    RG2=R(M2,1)
    RG3=R(M3,1)
    PG2=P(M2,1)
    PG3=P(M3,1)
    UPG2 = UP(M2,1)
    UPG3 = UP(M3,1)
    RPG2 = RP(M2,1)
    RPG3 = RP(M3,1)
    DUPDX = -RMBC*UPG2/DX
    ADC = DUPDX/CMB
    GPA2=GAM*P1/A1
    C22=GMRF*HAFF
    C31 = RW2F*SMDP(M1,1) - RP1*ADC
    RP2 = RP1 + C31*DT
    NTH=1
 10 CALL MOCINT(0.0,UG2,UG3,DXNO,UO)
    CALL MOCINT(P1 ,PG2,PG3,DXNO,PO)
    CALL MOCINT(R1 ,RG2,RG3,DXNO,RO)
    CALL MOCINT(0.0,UPG2,UPG3,DXNO,UPO)
    CALL MOCINT(RP1,RPG2,RPG3,DXNO,RPO)
    IF (MBC .EQ. -1) SMXO = DXO*CMB + SMB
    IF (MBC .EQ. 1) SMXO = (1.0 - DXO)*CMB + SMB
    CALL COMBNT(SMXO,1,KST,HAFO,SMDGO,SMDPO)
    AO=SQRT(PO/RO)
    CAPUO = (UO + RMBC*AO)/CMB
    GPAAVE=(GPA2+GAM*PO/AO)/2.00
    UMUP = UO - UPO
    SMU = SMDGO*UO
    RUUP = ABS(RO*UMUP)
    DGKVAR = DGK*(1.0 + DGKNL*RUUP**0.66666667)
    DKRUUP = DGKVAR*RPO*UMUP
```

```
      C2AVE = (C22 - RMBC*GAM*AO*(DKRUUP + RW2F*SMU) +
     1 GGM1*(RW2F*(SMDGO*HAFF/GM1 + (SMU*UO + SMDPO*UPO*UPO)/2.0)
     2 + DKRUUP*UMUP))/2.0
      P2 = PO + RMBC*GPAAVE*UO+C2AVE*DT
      ERR = (P2 - P2OLD)/P2OLD
      IF(ABS(ERR).LT.1.0E-07) GO TO 15
      IF(NTH.GT.20) GO TO 14
      P2OLD=P2
      NTH=NTH+1
      PG=P2**GM12G
      A2=PG*EXP(S2/G2)
      S2=S1+DT*(SINC1+GMRF*(HAFF-A2*A2)/P2)/2.00
      A2=PG*EXP(S2/G2)
      GPA2=GAM*P2/A2
      RP2 = RP1 + DT*(C31 + RW2F*SMDPO - RP2*ADC)/2.0
      CAPU2 = RMBC*A2/CMB
      DXO=RMBC*DT*(CAPU2+CAPUO)/2.00
      DXNO=DXO/DX
      GO TO 10
   14 WRITE(6,200) NTH,P2,P2OLD
   15 CONTINUE
      PUD(MM,1)=P2
      SUD(MM,1)=S2
      RNEW=EXP((ALOG(P2)-S2)/GAM)
      RUD(MM,1)=RNEW
      SSPUD(MM,1)=SQRT(P2/RNEW)
      UUD(MM,1)=0.00
      RPUD(MM,1) = RP2
      UPUD(MM,1) = 0.0
      RETURN
      END


      SUBROUTINE NOZMOC(KST)
C
C     ** THIS SUBROUTINE IS CORRECT FOR TWO PHASE FLOW - THE
C     PARTICLE FLOW IS COMPUTED AND D(LN(AREA))/DX=0.0**
C
      COMMON/FIXPR/MTOTA(5),GAM,GM1,GM12,GM12G,G2,GGM1,DGK,DGKNL
      COMMON/TIMTRN/DT,DT22,DXA(5),XISW(5),IDDA(5),ACMB(5),ASMB(5),
     1 ASMC(5)
      COMMON/SPCTRN/ CAPX(200,5),XI(200,5),SMX(200,5),
     1 RW2(200,5),DLNA(200,5)
      COMMON/COMFIX/ HAF(200,5),SMDG(200,5),SMDP(200,5),XIFC,HAFC,SMDGC
     1 ,REACTN,SMDPC
      COMMON/VARG/R(200,5),RP(200,5),U(200,5),UP(200,5),S(200,5)
     1,P(200,5),SSP(200,5)
      COMMON/VARUPD/ RUD(2,5),UUD(2,5),SUD(2,5),PUD(2,5),SSPUD(2,5),
     1               RPUD(2,5),UPUD(2,5)
      COMMON/NOZADM/ UBAR,PBAR,ADM
  200 FORMAT(/,*  ERROR IN NOZMOC   *,I4,4E14.8)
C
```

```
      CMB = ACMB(1)
      SMB = ASMB(1)
      DX = DXA(1)
      MTOT = MTOTA(1)
      RO = R(MTOT,1)
      PO = P(MTOT,1)
      P1OLD = PO
C
      U1 = U(MTOT,1)
      RP1 = RP(MTOT,1)
      UP1 = UP(MTOT,1)
      A1 = SSP(MTOT,1)
      SMDG1 = SMDG(MTOT,1)
      SMDP1 = SMDP(MTOT,1)
      SLOPE2 = U1/CMB
      SLOPE3 = (U1 + A1)/CMB
      SLOPE4 = UP1/CMB
C
      MTM1 = MTOT - 1
      MTM2 = MTOT - 2
      UG2 = U(MTM1,1)
      UG3 = U(MTM2,1)
      UPG2 = UP(MTM1,1)
      UPG3 = UP(MTM2,1)
      RG2 = R(MTM1,1)
      RG3 = R(MTM2,1)
      RPG2 = RP(MTM1,1)
      RPG3 = RP(MTM2,1)
      PG2 = P(MTM1,1)
      PG3 = P(MTM2,1)
      DUPDX = (UP1 - UPG2)/DX
C
      RW2F = RW2(MTOT,1)
      GMRF1 = GAM * SMDG(MTOT,1) * RW2F
      H1 = PO/RO
      HAFF = HAF(MTOT,1)
      UMUP = U1 - UP1
      RUUP = ABS(RO*UMUP)
      DGKVAR = DGK*(1.0 + DGKNL*RUUP**0.66666667)
      SMU = SMDG1*U1
      DKRUUP = DGKVAR*RP1*UMUP
      C2PART = RW2F*(SMDG1*HAFF/GM1 + (SMU*U1 + SMDP1*UP1*UP1)/2.0)
     1 + DKRUUP*UMUP
      C21 = (GGM1*C2PART - GMRF1*H1)/PO
      C31 = -GAM*A1*(DKRUUP + RW2F*SMU) + GGM1*C2PART
      IF (SMDPC .LE. 0.0) GO TO 9
      CU41 = DGKVAR*UMUP - RW2F*SMDP1*UP1/RP1
      CR41 = RP1*DUPDX/CMB - RW2F*SMDP1
    9 GPA1 = GAM * PO/A1
C
```

```
      NTH = 1
   10 DX2 = SLOPE2 * DT
      DX3 = SLOPE3 * DT
      DX4 = SLOPE4*DT
      DXN2 = DX2/DX
      DXN3 = DX3/DX
      DXN4 = DX4/DX
      CALL MOCINT(U1,UG2,UG3,DXN2,U2)
      CALL MOCINT(UP1,UPG2,UPG3,DXN2,UP2)
      CALL MOCINT(P0,PG2,PG3,DXN2,P2)
      CALL MOCINT(R0,RG2,RG3,DXN2,R2)
      CALL MOCINT(RP1,RPG2,RPG3,DXN2,RP2)
      CALL MOCINT(U1,UG2,UG3,DXN3,U3)
      CALL MOCINT(UP1,UPG2,UPG3,DXN3,UP3)
      CALL MOCINT(P0,PG2,PG3,DXN3,P3)
      CALL MOCINT(R0,RG2,RG3,DXN3,R3)
      CALL MOCINT(RP1,RPG2,RPG3,DXN3,RP3)
      CALL MOCINT(U1,UG2,UG3,DXN4,U4)
      CALL MOCINT(UP1,UPG2,UPG3,DXN4,UP4)
      CALL MOCINT(RP1,RPG2,RPG3,DXN4,RP4)
      SMX2 = (1.0 - DX2)*CMB + SMB
      SMX3 = (1.0 - DX3)*CMB + SMB
      SMX4 = (1.0 - DX4)*CMB + SMB
      CALL COMBNT(SMX2,KST,KST,HAF2,SMDG2,SMDP2)
      CALL COMBNT(SMX3,KST,KST,HAF3,SMDG3,SMDP3)
      CALL COMBNT(SMX4,KST,KST,HAF4,SMDG4,SMDP4)
C
      H2 = P2/R2
      UMUP = U2 - UP2
      RUUP = ABS(R2*UMUP)
      DGKVAR = DGK*(1.0 + DGKNL*RUUP**0.66666667)
      SMU = SMDG2*U2
      DKRUUP = DGKVAR*RP2*UMUP
      C22 = GGM1*(RW2F*(SMDG2*(HAFF-H2)/GM1 +
     1      (SMU*U2 + SMDP2*UP2*UP2)/2.0) + DKRUUP*UMUP)/P2
      A3 = SQRT(P3/R3)
      UMUP = U3 - UP3
      RUUP = ABS(R3*UMUP)
      DGKVAR = DGK*(1.0 + DGKNL*RUUP**0.66666667)
      SMU = SMDG3*U3
      DKRUUP = DGKVAR*RP3*UMUP
      C33 = -GAM*A3*(DKRUUP + RW2F*SMU) +
     1      GGM1*(RW2F*(SMDG3*HAFF/GM1 + (SMU*U3 +
     2      SMDP3*UP3*UP3)/2.0) + DKRUUP*UMUP)
      GPAAVE = (GPA1 + GAM*P3/A3)/2.00
      C2AVE = (C21 + C22)/2.0
      C3AVE = (C31 + C33)/2.0
      IF (SMDPC .LE. 0.0) GO TO 12
      CU4AVE = (CU41 + DGKVAR*(U4-UP4) - RW2F*SMDP4*UP4/RP4)/2.0
      CR4AVE = (CR41 + RP4*DUPDX/CMB - RW2F*SMDP4)/2.0
      GO TO 13
   12 CU4AVE = 0.0
      CR4AVE = 0.0
```

```
C
   13 S2 = ALOG(P2) - GAM*ALOG(R2)
      S1 = S2 + C2AVE*DT
      PNUM = P3 + GPAAVE * (U3 - UBAR + ADM*PBAR) + C3AVE*DT
      P1 = PNUM/(1.0 + GPAAVE*ADM)
      U1 = UBAR + ADM*(P1-PBAR)
      R1 = EXP((ALOG(P1) - S1)/GAM)
      A1 = SQRT(P1/R1)
      UP1 = UP4 + CU4AVE*DT
      RP1 = RP4 - CR4AVE*DT
C
      ERR = (P1 - P1OLD)/P1OLD
      IF (ABS(ERR) .LT. 1.0E-07)  GO TO 15
      IF (NTH .GT. 20) GO TO 14
      P1OLD = P1
      NTH = NTH + 1
C
      H1 = P1/R1
      UMUP = U1 - UP1
      RUUP = ABS(R1*UMUP)
      DGKVAR = DGK*(1.0 + DGKNL*RUUP**0.66666667)
      SMU = SMDG1*U1
      DKRUUP = DGKVAR*RP1*UMUP
      C2PART = RW2F*(SMDG1*HAFF/GM1 + (SMU*U1 + SMDP1*UP1*UP1)/2.0)
     1         + DKRUUP*UMUP
      C21 = (GGM1*C2PART - GMRF1*H1)/P1
      C31 = -GAM*A1*(DKRUUP + RW2F*SMU) + GGM1*C2PART
      GPA1 = GAM * P1/A1
      SLP21 = U1/CMB
      SLP22 = U2/CMB
      SLOPE2 = (SLP21 + SLP22)/2.0
      SLP31 = (U1 + A1)/CMB
      SLP33 = (U3 + A3)/CMB
      SLOPE3 = (SLP31 + SLP33)/2.0
      SLP41 = UP1/CMB
      SLP44 = UP4/CMB
      SLOPE4 = (SLP41 + SLP44)/2.0
      GO TO 10
   14 WRITE(6,200) NTH,P1,P1OLD
   15 CONTINUE
C
      PUD(2,1) = P1
      SUD(2,1) = S1
      RUD(2,1) = R1
      UUD(2,1) = U1
      SSPUD(2,1) = A1
      RPUD(2,1) = RP1
      UPUD(2,1) = UP1
      RETURN
      END
```

```
      SUBROUTINE TAYLOR(KS)
      COMMON/VARG/R(200,5),RP(200,5),U(200,5),UP(200,5),S(200,5)
     1,P(200,5),SSP(200,5)
      COMMON/FIXPR/MTOTA(5),GAM,GM1,GM12,GM12G,G2,GGM1,DGK,DGKNL
      COMMON/COMFIX/ HAF(200,5),SMDG(200,5),SMDP(200,5),XIFC,HAFC,SMDGC
     1 ,REACTN,SMDPC
      COMMON/TIMTRN/DT,DT22,DXA(5),XISW(5),IDDA(5),ACMB(5),ASMB(5),
     1 ASMC(5)
      COMMON/SPCTRN/ CAPX(200,5),XI(200,5),SMX(200,5),
     1 RW2(200,5),DLNA(200,5)
      COMMON/DDMG/ SMDDG(200,5)
C     ** R    IS   RHO(GAS)                  **
C     ** RP   IS   RHO(PARTICLES)            **
C     ** U    IS   VELOCITY(GAS)             **
C     ** UP   IS   VELOCITY(PARTICLES)       **
C     ** S    IS   ENTROPY(GAS)              **
C     *** CORRECTIONS HAVE BEEN MADE FOR NEW PARTICLE MOMENTUM EQUATION*
C     *** AS OF LEVINES REPORT ---
C****** THIS SUBROUTINE VALID FOR GAS AND PARTICLE FLOWS *******
C****** INCLUDES NONLINEAR DRAG LAW ******
      MF=MTOTA(KS)-1
      DX=DXA(KS)
      TWDX=2.00*DX
      DX2=DX*DX
      CMB=ACMB(KS)
      R1=R(1,KS)
      RP1 = RP(1,KS)
      U1=U(1,KS)
      UP1 = UP(1,KS)
      S1=S(1,KS)
      P1=P(1,KS)
      H1=P1/R1
      RW21=RW2(1,KS)
      DLNA1=DLNA(1,KS)
      SMDG1=SMDG(1,KS)
      SMDP1 = SMDP(1,KS)
      HAF1=HAF(1,KS)
      R51 = 0.0
      R52 = 0.0
      R53 = 0.0
      R5T = 0.0
      R11=SMDG1*RW21-R1*U1*DLNA1
      R21 = SMDP1*RW21 - RP1*UP1*DLNA1
      UMUP1 = U1 - UP1
      RUUP1 = ABS(R1*UMUP1)
      DGKVR1 = DGK*(1.0 + DGKNL*RUUP1**0.66666667)
      SMU1=SMDG1*U1
      SMUP1 = SMDP1*UP1
      DKRUUP = DGKVR1*RP1*UMUP1
      R31=-(DKRUUP + RW21*SMU1)/R1
      R41 = GGM1 * (RW21*(SMDG1*(HAF1-H1)/GM1 + (SMU1*U1
     1      + SMUP1*UP1)/2.00) + DKRUUP*UMUP1)/P1
      IF (SMDPC .GT. 0.0) R51 = (DKRUUP - RW21*SMUP1)/RP1
      R2=R(2,KS)
      RP2 = RP(2,KS)
```

```
      U2=U(2,KS)
      UP2 = UP(2,KS)
      S2=S(2,KS)
      P2=P(2,KS)
      H2=P2/R2
      RW22=RW2(2,KS)
      DLNA2=DLNA(2,KS)
      SMDG2=SMDG(2,KS)
      SMDP2 = SMDP(2,KS)
      HAF2=HAF(2,KS)
      R12=SMDG2*RW22-R2*U2*DLNA2
      R22 = SMDP2*RW22 - RP2*UP2*DLNA2
      UMUP2 = U2 - UP2
      RUUP2 = ABS(R2*UMUP2)
      DGKVR2 = DGK*(1.0 + DGKNL*RUUP2**0.66666667)
      SMU2=SMDG2*U2
      SMUP2 = SMDP2*UP2
      DKRUUP = DGKVR2*RP2*UMUP2
      R32=-(DKRUUP + RW22*SMU2)/R2
      R42=GGM1*(RW22*(SMDG2*(HAF2-H2)/GM1+(SMU2*U2
     1   +SMUP2*UP2)/2.00)+DKRUUP*UMUP2)/P2
      IF (SMDPC .GT. 0.0) R52 = (DKRUUP - RW22*SMUP2)/RP2
C
C     ** THESE ARE TEMPORARY ASSIGNMENTS ONLY **
      HAFD2=0.00
C
      DO 100 M=2,MF
      SMDDG2=SMDDG(M,KS)
      SMDDP2 = SMDPC*SMDDG2
      CU2 = U2/CMB
      CUP2 = UP2/CMB
      ETA2=1.0/CMB
      M3=M+1
      R3=R(M3,KS)
      RP3 = RP(M3,KS)
      U3=U(M3,KS)
      UP3 = UP(M3,KS)
      S3=S(M3,KS)
      P3=P(M3,KS)
      H3=P3/R3
      RW23=RW2(M3,KS)
      DLNA3=DLNA(M3,KS)
      SMDG3=SMDG(M3,KS)
      SMDP3 = SMDP(M3,KS)
      HAF3=HAF(M3,KS)
      R13=SMDG3*RW23-R3*U3*DLNA3
      R23 = SMDP3*RW23 - RP3*UP3*DLNA3
      UMUP3 = U3 - UP3
      RUUP3 = ABS(R3*UMUP3)
      DGKVR3 = DGK*(1.0 + DGKNL*RUUP3**0.66666667)
      SMU3=SMDG3*U3
      SMUP3 = SMDP3*UP3
      DKRUUP = DGKVR3*RP3*UMUP3
      R33=-(DKRUUP + RW23*SMU3)/R3
      R43=GGM1*(RW23*(SMDG3*(HAF3-H3)/GM1+(SMU3*U3
     1   +SMUP3*UP3)/2.00) + DKRUUP*UMUP3)/P3
```

```
      IF (SMDPC .GT. 0.0) R53 = (DKRUUP - RW23*SMUP3)/RP3
      RX=(R3-R1)/TWDX
      RPX = (RP3 - RP1)/TWDX
      UX=(U3-U1)/TWDX
      UPX = (UP3 - UP1)/TWDX
      SX=(S3-S1)/TWDX
      PX=(P3-P1)/TWDX
      HX=(PX-H2*RX)/R2
      EGR2=ETA2/(GAM*R2)
      RT=R12-(CU2*RX+ETA2*R2*UX)
      RPT = R22 - (CUP2*RPX + ETA2*RP2*UPX)
      UT=R32-(CU2*UX+EGR2*PX)
      ST=R42-CU2*SX
      UPT = R52 - CUP2*UPX
      PT=P2*ST+GAM*H2*RT
      HT=(PT-H2*RT)/R2
      CUX = ETA2*UX
      CUPX = ETA2*UPX
      CUT = UT/CMB
      CUPT = UPT/CMB
      RXX=(R3-2.00*R2+R1)/DX2
      RPXX = (RP3 - 2.00*RP2 +RP1)/DX2
      UXX=(U3-2.00*U2+U1)/DX2
      UPXX = (UP3 - 2.00*UP2 +UP1)/DX2
      SXX=(S3-2.00*S2+S1)/DX2
      PXX=(P3-2.00*P2+P1)/DX2
      R1X=(R13-R11)/TWDX
      R2X = (R23 - R21)/TWDX
      R3X=(R33-R31)/TWDX
      R4X=(R43-R41)/TWDX
      R5X = (R53 - R51)/TWDX
      RTX=R1X-(CUX*RX+CU2*RXX+ETA2*(RX*UX+R2*UXX))
      RPTX = R2X - (CUPX*RPX + CUP2*RPXX + ETA2*(RPX*UPX + RP2*UPXX))
      UTX=R3X-(CUX*UX+CU2*UXX+EGR2*(PXX-PX*RX/R2))
      STX=R4X-(CUX*SX+CU2*SXX)
      UPTX = R5X - (CUPX*UPX + CUP2*UPXX)
      PTX=PX*ST+P2*STX+GAM*(HX*RT+H2*RTX)
      R1T=RW22*SMDDG2-(RT*U2+R2*UT)*DLNA2
      R2T = RW22*SMDDP2 - (RPT*UP2 + RP2*UPT)*DLNA2
      UTMUPT = UT - UPT
      RTUMUP = RPT*UMUP2
      RUTMPT = RP2*UTMUPT
      IF (SMDPC .LE. 0.0) GO TO 80
      IF (UMUP2) 50, 80, 60
   50 AUMUPT = -UTMUPT
      GO TO 70
   60 AUMUPT = UTMUPT
   70 VARKT = 0.66666667*DGK*DGKNL*(RT*ABS(UMUP2)+R2*AUMUPT)/
     1        (RUUP2**0.33333333)
      GO TO 90
   80 VARKT = 0.0
   90 R3T = -(R32*RT + DGKVR2*(RTUMUP + RUTMPT) + VARKT*RP2*UMUP2
     1    + RW22*(UT*SMDG2 + U2*SMDDG2))/R2
```

```
      R4T=(GGM1*(RW22*((SMDDG2*(HAF2-H2)+SMDG2*(HAFD2-HT))/GM1+
     1 (SMDDG2*U2*U2 + SMDDP2*UP2*UP2)/2.00
     2 + (SMU2*UT + SMUP2*UPT)) +
     3   DGKVR2*UMUP2*(RTUMUP + 2.00*RUTMPT) + VARKT*RP2*UMUP2)
     4       - R42*PT)/P2
      IF (SMDPC .LE. 0.0) GO TO 91
      R5T = DGKVR2*UTMUPT + VARKT*UMUP2 - RW22*(UPT*SMDG2 + UP2*SMDDG2
     1       - SMUP2*(RPT/RP2))/RP2
   91 RTT=R1T-(CUT*RX+CU2*RTX+ETA2*(UX*RT+R2*UTX))
      RPTT = R2T - (CUPT*RPX + CUP2*RPTX
     1       + ETA2*(UPX*RPT + RP2*UPTX))
      UTT=R3T-(CUT*UX+CU2*UTX+EGR2*(PTX-PX*RT/R2))
      STT=R4T-(CUT*SX+CU2*STX)
      UPTT = R5T - (CUPT*UPX + CUP2*UPTX)
      RFMKS=R2+RT*DT+RTT*DT22
      R(M,KS)=RFMKS
      U(M,KS)=U2+UT*DT+UTT*DT22
      IF (SMDPC .LE. 0.0) GO TO 92
      RP(M,KS) = RP2 + RPT*DT + RPTT*DT22
      UP(M,KS) = UP2 + UPT*DT + UPTT*DT22
      GO TO 94
   92 RP(M,KS) = RP2
      UP(M,KS) = UP2
   94 SFMKS=S2+ST*DT+STT*DT22
      S(M,KS)=SFMKS
      PFMKS=EXP(SFMKS+GAM*ALOG(RFMKS))
      P(M,KS)=PFMKS
      SSP(M,KS)=SQRT(PFMKS/RFMKS)
      R1=R2
      RP1 = RP2
      U1=U2
      UP1 = UP2
      S1=S2
      P1=P2
      R2=R3
      RP2 = RP3
      U2=U3
      UP2 = UP3
      S2=S3
      P2=P3
      H2=H3
      SMDG2=SMDG3
      SMDP2 = SMDP3
      HAF2=HAF3
      DLNA2=DLNA3
      RW22=RW23
      UMUP2 = UMUP3
      RUUP2 = RUUP3
      DGKVR2 = DGKVR3
      SMU2=SMU3
      SMUP2 = SMUP3
```

```
      R11=R12
      R21 = R22
      R31=R32
      R41=R42
      R51 = R52
      R12=R13
      R22 = R23
      R32=R33
      R42=R43
      R52 = R53
  100 CONTINUE
      RETURN
      END


      SUBROUTINE NUTEMP(KST,NOPT,NT)
      COMMON/TIMTRN/DT,DT22,DXA(5),XISW(5),IDDA(5),ACMB(5),ASMB(5),
     1 ASMC(5)
      COMMON/SPCTRN/ CAPX(200,5),XI(200,5),SMX(200,5),
     1 RW2(200,5),DLNA(200,5)
      COMMON/VARG/R(200,5),RP(200,5),U(200,5),UP(200,5),S(200,5)
     1,P(200,5),SSP(200,5)
      COMMON/MSFSLD/ SMXBS(100),APLOC(100),FSMDG(100),DXSBS,NBS,APC(100)
      COMMON/BRNCON/ DYA(3),NTY(3),ALFTA(3),TYLOC(50),YO,Z1,Z2P,WCON,
     1EORG,EORS,ETF,QMC,BRAY,JTOT,JTOTM1,ARSTR,RHRSTR,Z1T,TS
      APLOC(1)=P(1,1)
      IF(KST.GT.1) GO TO 30
C      KST=1,   HENCE ONLY ONE REGION INTERPOLATION NEEDED
    8 ML=2
      DO 20 IBS=2,NBS
      SMXBSI=SMXBS(IBS)
    9 IF(SMXBSI.LE.SMX(ML,1)) GO TO 10
      ML=ML+1
      GO TO 9
   10 ML1=ML-1
      SMX1=SMX(ML1,1)
      P1=P(ML1,1)
      APLOC(IBS)=((P(ML,1)-P1)/(SMX(ML,1)-SMX1))*(SMXBSI-SMX1) + P1
   20 CONTINUE
      GO TO 71
C      KST.GT.1   MULTIPLE REGION INTERPOLATION NEEDED
   30 ML=2
      KSL=1
      CMBL=ACMB(1)
      SMBL=ASMB(1)
      XKSEND = CMBL + SMBL
      DO 70 IBS=2,NBS
      SMXBSI=SMXBS(IBS)
   38 IF(SMXBSI.GT.XKSEND) GO TO 50
   39 IF(SMXBSI.LE.SMX(ML,KSL)) GO TO 40
      ML=ML+1
      GO TO 39
```

```
40 ML1=ML-1
   SMX1=SMX(ML1,KSL)
   P1=P(ML1,KSL)
   APLOC(IBS)=((P(ML,KSL)-P1)/(SMX(ML,KSL)-SMX1))*(SMXBSI-SMX1) + P1
   GO TO 70
50 ML=2
   KSL=KSL+1
   CMBL=ACMB(KSL)
   SMBL=ASMB(KSL)
   XKSEND = CMBL + SMBL
   GO TO 38
70 CONTINUE
71 IF (NT .EQ. 0) GO TO 100
75 IF (NOPT.EQ.2) GO TO 80
   DO 78 IBS = 1,NBS
   PDEL = APLOC(IBS) - APC(IBS)
   CALL LINTHW(IBS,PDEL)
78 CONTINUE
   GO TO 100
80 DO 90 IBS=1,NBS
   CALL THRMWV(IBS,APLOC(IBS),TFLM,NT)
90 CONTINUE
100 CONTINUE
   RETURN
   END

   SUBROUTINE THRMWV(IBS,PLOC,TFLM,NT)
   COMMON/TEMWAV/CT(101,20),CNU(101,20),SW(101,20),SV(101,20),RGR(20)
   COMMON/MSFSLD/ SMXBS(100),APLOC(100),FSMDG(100),DXSBS,NBS,APC(100)
   COMMON/BRNCON/ DYA(3),NTY(3),ALFTA(3),TYLOC(50),YO,Z1,Z2P,WCON,
  1EORG,EORS,ETF,QMC,BRAY,JTOT,JTOTM1,ARSTR,RHRSTR,Z1T,TS
   COMMON/TIMTRN/DT,DT22,DXA(5),XISW(5),IDDA(5),ACMB(5),ASMB(5),
  1 ASMC(5)
   DIMENSION SAVE(8)
250 FORMAT(2X,*  STEP=*,I5,*  IBS=*,I2,*   ITSUB D.N.C. IN THRMWV FOR
  1 PLOC=*,E14.8,*  CTS=*,E14.8,*  CAPF=*,E14.8)
   IF (PLOC .LT. 10.00)  PLOC = 10.00
   VSTR=VCON*PLOC*PLOC*ETF
   Z2=Z2P*VSTR
   R=RGR(IBS)
   ROT=R/2.00
   SQR=SQRT(ROT*ROT + 1.00/DT)
   XI1=SQR-ROT
   XI2=-(SQR+ROT)
   XID=XI2-XI1
   CNU(1,IBS)=0.00
   DO 20 J=2,JTOT
   Y=TYLOC(J)+YO
   EXID=EXP(XID*Y)
   CNUJB=(1.00-EXID)/(XI1*EXID-XI2)
   IF(ABS(CNUJB-CNU(J-1,IBS)).LT.1.0E-07) GO TO 22
   CNU(J,IBS)=CNUJB
20 CONTINUE
```

```
      GO TO 24
   22 CNU(J,IBS)=CNUJB
      JST=J+1
      Y=TYLOC(JST)+YO
      EXID=EXP(XID*Y)
      CNUFX=(1.00-EXID)/(XI1*EXID-XI2)
      DO 23 J=JST,JTOT
      CNU(J,IBS)=CNUFX
   23 CONTINUE
   24 CONTINUE
      SW(1,IBS)=1.00
      CNUJ=0.00
      CTJ=CT(1,IBS)
      SWJ=1.00
      NF=0
      DO 31 I=1,3
      NI=NF+1
      NF=NF+NTY(I)
      ALFT=ALFTA(I)
      DO 30 J=NI,NF
      JP1=J+1
      CNUJP1=CNU(JP1,IBS)
      CTJP1=CT(JP1,IBS)
      SWJP1=(SWJ*(1.00-ALFT*CNUJ)+ALFT*(CNUJP1*CTJP1+CNUJ*CTJ))
     1  /(1.00+ALFT*CNUJP1)
      SW(JP1,IBS)=SWJP1
      SWJ=SWJP1
      CTJ=CTJP1
      CNUJ=CNUJP1
   30 CONTINUE
   31 CONTINUE
      CNUL=CNU(JTOT,IBS)
      SWL=SW(JTOT,IBS)
      CTS = CT(JTOT,IBS)
      SAVE(1)=1.00
      SAVE(2)=0.010*CTS
   35 EETS=EXP(EORS/CTS)
      GH=-((Z1 + Z1T*(CTS-TS))/EETS) + Z2*EETS
      CAPF=-CTS + CNUL*GH+SWL
      CALL ITSUB(CAPF,CTS,SAVE,0.000001,50)
      KBR=SAVE(1)
      GO TO (35,35,35,35,41,40),KBR
   40 WRITE(6,250) NT,IBS,PLOC,CTS,CAPF
   41 EETS=EXP(EORS/CTS)
      R=BRAY/EETS
      ROT = R/2.00
      GH=-((Z1 + Z1T*(CTS-TS))/EETS) + Z2*EETS
      SV(JTOT,IBS)=GH
      SWJ=SWL
      CNUJ=CNUL
      CTJ=CT(JTOT,IBS)
      SVJ=GH
      NF=0
```

```
      DO 51 II=1,3
      I=4-II
      NI=NF+1
      NF=NF+NTY(I)
      ALFT=ALFTA(I)
      BETN=DYA(I)*ROT
      DO 50 N=NI,NF
      JM1=JTOT - N
      SWJM1=SW(JM1,IBS)
      CNUJM1=CNU(JM1,IBS)
      CTJM1=CT(JM1,IBS)
      SVJM1=(SVJ*(1.00-BETN-ALFT*CNUJ)-ALFT*(SWJ+SWJM1-CTJ-CTJM1))
     1  /(1.00+BETN+ALFT*CNUJM1)
      SV(JM1,IBS)=SVJM1
      SVJ=SVJM1
      SWJ=SWJM1
      CNUJ=CNUJM1
      CTJ=CTJM1
   50 CONTINUE
   51 CONTINUE
      DO 60 J=1,JTOT
      CT(J,IBS)=CNU(J,IBS)*SV(J,IBS) + SW(J,IBS)
   60 CONTINUE
      RGR(IBS)=R
      FSMDG(IBS)=QMC*R
      RETURN
      END


      SUBROUTINE LINTHW(IBS,PDEL)
      COMMON/TEMWAV/CT(101,20),CNU(101,20),SW(101,20),SV(101,20),RGR(20)
      COMMON/MSFSLD/ SMXBS(100),APLOC(100),FSMDG(100),DXSBS,NBS,APC(100)
      COMMON/BRNCON/ DYA(3),NTY(3),ALFTA(3),TYLOC(50),YO,Z1,Z2P,WCON,
     1EORG,EORS,ETF,QMC,BRAY,JTOT,JTOTM1,ARSTR,RHRSTR,Z1T,TS
      COMMON/TIMTRN/ DT,DT22,DXA(5),XISW(5),IDDA(5),ACMB(5),ASMB(5),
     1 ASMC(5)
      COMMON/SSVAL/ RBAR(20),CTBAR(101,20),CTYBAR(101,20),
     1              Z2RP(20),ETGH(20),ERTS(20)
  203 FORMAT (2X,*ITERATION ON R FAILED TO CONVERGE*,5X,
     1          *ROLD = *,E14.8,*    RNEW = *,E14.8)
C
      ROT = RBAR(IBS)/2.0
      SQR=SQRT(ROT*ROT + 1.00/DT)
      CNU(1,IBS)=0.00
      DO 20 J=2,JTOT
      Y = TYLOC(J) + YO
      ALPHA = SQR * Y
      SINHA = (EXP(ALPHA) - EXP(-ALPHA))/2.0
      COSHA = (EXP(ALPHA) + EXP(-ALPHA))/2.0
      CNUJB = SINHA/(SQR*COSHA + ROT*SINHA)
      IF(ABS(CNUJB-CNU(J-1,IBS)).LT.1.0E-07) GO TO 22
      CNU(J,IBS)=CNUJB
   20 CONTINUE
```

```
      GO TO 24
   22 CNU(J,IBS) = CNUJB
      JST = J + 1
      Y = TYLOC(JST) + YO
      ALPHA = SQR * Y
      SINHA = (EXP(ALPHA) - EXP(-ALPHA))/2.0
      COSHA = (EXP(ALPHA) + EXP(-ALPHA))/2.0
      CNUFX = SINHA/(SQR*COSHA + ROT*SINHA)
      DO 23 J = JST,JTOT
      CNU(J,IBS) = CNUFX
   23 CONTINUE
   24 CONTINUE
C
      NSW = 0
      SW(1,IBS) = 0.0
      CNUJ=0.00
      RDEL = RGR(IBS) - RBAR(IBS)
   25 ROLD = RDEL
      CTDEL = CT(1,IBS) - CTBAR(1,IBS)
      CHJ = CTDEL - RDEL*CTYBAR(1,IBS)*DT
      SWJ = 0.0
      NF=0
      DO 31 I=1,3
      NI=NF+1
      NF=NF+NTY(I)
      ALFT=ALFTA(I)
      DO 30 J=NI,NF
      JP1=J+1
      CNUJP1=CNU(JP1,IBS)
      CTDEL = CT(JP1,IBS) - CTBAR(JP1,IBS)
      CHJP1 = CTDEL - RDEL*CTYBAR(JP1,IBS)*DT
      SWJP1=(SWJ*(1.00-ALFT*CNUJ)+ALFT*(CNUJP1*CHJP1+CNUJ*CHJ))
     1 /(1.00+ALFT*CNUJP1)
      SW(JP1,IBS)=SWJP1
      SWJ=SWJP1
      CHJ=CHJP1
      CNUJ=CNUJP1
   30 CONTINUE
   31 CONTINUE
C
      CNUL=CNU(JTOT,IBS)
      SWL=SW(JTOT,IBS)
      SVL = (Z8RP(IBS)*PDEL - ETGH(IBS)*SWL)/(1.0 + CNUL*ETGH(IBS))
      SV(JTOT,IBS) = SVL
      CTSDEL = CNUL*SVL + SWL
      RDEL = ERTS(IBS)*CTSDEL
      IF (ABS(RDEL-ROLD) .LT. 1.0E-06) GO TO 40
      IF (NSW .GT. 15) GO TO 39
      NSW = NSW + 1
      GO TO 25
   39 WRITE (6,203) ROLD, RDEL
   40 CONTINUE
C
```

```
      SWJ=SWL
      CNUJ=CNUL
      CTDEL = CT(JTOT,IBS) - CTBAR(JTOT,IBS)
      CHJ = CTDEL - RDEL*CTYBAR(JTOT,IBS)*DT
      SVJ = SVL
      NF=0
      DO 51 II=1,3
      I = 4 - II
      NI=NF+1
      NF=NF+NTY(I)
      ALFT=ALFTA(I)
      BETN=DYA(I)*ROT
      DO 50 N=NI,NF
      JM1=JTOT - N
      SWJM1=SW(JM1,IBS)
      CNUJM1=CNU(JM1,IBS)
      CTDEL = CT(JM1,IBS) - CTBAR(JM1,IBS)
      CHJM1 = CTDEL - RDEL*CTYBAR(JM1,IBS)*DT
      SVJM1=(SVJ*(1.00-BETN-ALFT*CNUJ)-ALFT*(SWJ+SWJM1-CHJ-CHJM1))
     1  /(1.00+BETN+ALFT*CNUJM1)
      SV(JM1,IBS)=SVJM1
      SVJ=SVJM1
      SWJ=SWJM1
      CNUJ=CNUJM1
      CHJ=CHJM1
   50 CONTINUE
   51 CONTINUE
C
      DO 60 J=1,JTOT
      CTDEL = CNU(J,IBS)*SV(J,IBS) + SW(J,IBS)
      CT(J,IBS) = CTBAR(J,IBS) + CTDEL
   60 CONTINUE
      R = RBAR(IBS) + RDEL
      RGR(IBS)=R
      FSMDG(IBS)=QMC*R
      RETURN
      END


      SUBROUTINE COMBNT(XND,KS,KST,HAFL,SMDGL,SMDPL)
      COMMON/TIMTRN/DT,DT22,DXA(5),XISW(5),IDDA(5),ACMB(5),ASMB(5),
     1 ASMC(5)
      COMMON/NOZDAT/ELSTR,RCHSTR,UT
      COMMON/COMFIX/ HAF(200,5),SMDG(200,5),SMDP(200,5),XIFC,HAFC,SMDGC
     1 ,REACTN,SMDPC
      COMMON/MSFSLD/ SMXBS(100),APLOC(100),FSMDG(100),DXSBS,NBS,APC(100)
  400 FORMAT(/,*       COMBNT ERROR - 3 POSSIBLE CASE FAILURE ---*,/,5X,
     1*KS=*,I2,*  KST=*,I2,*    (XST,XSMND,XMEND,XMBND,XJ1,XJ2)*,6E13.7)
  401 FORMAT(/,*      IN COMBNT - A ONE POINT INTERPOLATION HAS BEEN FORC
     1ED --- R.E.I.*,/,5X,*KS=*,I2,*  KST=*,I2,*
     2MND,XMEND,XMBND)*,2I5,2E14.8,/,15X,6E14.8)
  402 FORMAT(/,*      IN COMBNT - A ONE POINT INTERPOLATION HAS BEEN FORC
     1ED --- L.E.I.*,/,5X,*KS=*,I2,*  KST=*,I2,*
     2MND,XMEND,XMBND)*,2I5,2E14.8,/,15X,6E14.8)
```

```
      XST=XND*ELSTR
      IF(XST.LE.0.0) GO TO 10
      SMDGL=0.00
      GO TO 200
   10 XSM=ELSTR + XST
      XSMND=XSM/DXSBS
      J1=1 + XSMND
      XJ1=(J1-1)
      XJ2=J1
      J2=J1 + 1
      IF(KST.GT.1) GO TO 20
   15 FSMDG1=FSMDG(J1)
      SMDGL=(FSMDG(J2)-FSMDG1)*(XSMND-XJ1) + FSMDG1
      GO TO 200
   20 CMB=ACMB(KS)
      SMB=ASMB(KS)
      SMXE = CMB + SMB
      SMXB = SMB
      XMEND=(SMXE*ELSTR + ELSTR)/DXSBS
      XMBND = (SMXB*ELSTR + ELSTR)/DXSBS
      IF(XJ2.LT.XMEND.AND.XJ1.GE.XMBND) GO TO 15
      IF(XJ2.GT.XMEND) GO TO 30
      IF(XJ1.LT.XMBND) GO TO 40
      WRITE(6,400) KS,KST,XST,XSMND,XMEND,XMBND,XJ1,XJ2
      STOP
   30 J0 = J1 + 1
      XJ0 = J0 - 1
      IF (XJ0 .LT. XMBND) GO TO 35
      FSMDG1 = FSMDG(J1)
      SMDGL = (FSMDG1 - FSMDG(J0)) * (XSMND - XJ1) + FSMDG1
      GO TO 200
   35 SMDGL=FSMDG(J1)
      WRITE(6,401) KS,KST,J1,J0,XJ1,XJ0,XST,XSMND,XMEND,XMBND
      GO TO 200
   40 J3 = J2 + 1
      IF (J3 .GT. NBS) GO TO 45
      XJ3 = J2
      IF (XJ3 .GT. XMEND) GO TO 45
      FSMDG2 = FSMDG(J2)
      SMDGL = (FSMDG(J3)-FSMDG2)*(XSMND-XJ2) + FSMDG2
      GO TO 200
   45 SMDGL = FSMDG(J2)
      WRITE(6,402) KS,KST,J2,J3,XJ2,XJ3,XST,XSMND,XMEND,XMBND
  200 HAFL=HAFC
      SMDPL = SMDPC*SMDGL
      RETURN
      END
```

```
      SUBROUTINE MOCINT(Y1,Y2,Y3,DXN,YO)
      C1 = Y1 - Y2
      C3 = Y3 - Y2
      A = 0.500 * (C1 + C3)
      B = -0.500 * (3.00*C1 + C3)
      YO=A*DXN*DXN+B*DXN+Y1
      RETURN
      END
```

```
      SUBROUTINE SHDETL(U1,U2,U3,U4,SHDET,NYES)
      NYES=0
      V31 = U3 - 2.00*U2 + U1
      V41 = U4 - 2.00*U3 + U2
      U22=U2*U2
      U32=U3*U3
      U42=U4*U4
      U12 = U1*U1
      V32 = U32 - 2.00*U22 + U12
      V42 = U42 - 2.00*U32 + U22
      U33 = U32*U3
      U23 = U22*U2
      V33 = U33 - 2.00*U23 + U12*U1
      V43 = U42*U4 - 2.00*U33 + U23
      A = V31*V42 - V32*V41
      B = V33*V41 - V31*V43
      C = V32*V43 - V33*V42
      DSHDET = B*B - 3.00*A*C
      IF (DSHDET .LT. 0.000005) GO TO 20
      IF (ABS(V31) .LT. 0.1E-06) GO TO 20
      IF (ABS(V41) .LT. 0.1E-06) GO TO 20
      SD = SQRT(DSHDET)
      UR1 = (-B + SD)/(3.00*A)
      UR2 = (-B - SD)/(3.00*A)
      IF (U1 .GT. U4) GO TO 15
      IF (UR1 .GT. U1 .AND. UR1 .LT. U4) NYES = 1
      IF (UR2 .GT. U1 .AND. UR2 .LT. U4) NYES = 1
      GO TO 20
   15 CONTINUE
      IF (UR1 .LT. U1 .AND. UR1 .GT. U4) NYES = 1
      IF (UR2 .LT. U1 .AND. UR2 .GT. U4) NYES = 1
   20 SHDET = DSHDET
      RETURN
      END
```

```
      SUBROUTINE ITSUB(FOFY,Y,SAVE,CONV,NTIMES)
      DIMENSION SAVE(8)
      N1=SAVE(3) + .1
      FOFXCK=SAVE(8)
      FOFX=FOFY
      X=Y
      IF(ABS(FOFX)-CONV.LE.0.) GO TO 110
      ITIME=SAVE(1) + .1
      GO TO (10,30,50,70),ITIME
   10 N1=1
      ITIME=2
      FOFXCK=FOFX
      SAVE(8)=FOFXCK
      IF(FOFX.LT.0.) GO TO 50
   30 IF(FOFX.LT.0.) GO TO 70
      IF(FOFXCK.GE.FOFX) GO TO 35
      SAVE(2)=-1.*SAVE(2)
      X=X-2.*SAVE(2)
      GO TO 90
   35 SAVE(4)=X
      SAVE(5)=FOFX
      X=X-SAVE(2)
      GO TO 90
   50 ITIME=3
      IF(FOFX.GT.0.) GO TO 70
      IF(FOFXCK.LE.FOFX) GO TO 55
      SAVE(2)=-1.*SAVE(2)
      X=X+2.*SAVE(2)
      GO TO 90
   55 SAVE(6)=X
      SAVE(7)=FOFX
      X=X+SAVE(2)
      GO TO 90
   70 ITIME=4
      N1=SAVE(3)
      IF(FOFX.LT.0.) GO TO 75
      SAVE(4)=X
      SAVE(5)=FOFX
      GO TO 80
   75 SAVE(6)=X
      SAVE(7)=FOFX
   80 X=SAVE(4)-SAVE(5)*((SAVE(6)-SAVE(4))/(SAVE(7)-SAVE(5)))
   90 IF(N1.GE.NTIMES) GO TO 100
      N1=N1+1
      SAVE(3)=N1
      GO TO 120
  100 ITIME=6
      GO TO 120
  110 ITIME=5
      SAVE(4)=X
      SAVE(5)=FOFX
      SAVE(6)=X
      SAVE(7)=FOFX
  120 SAVE(1)=FLOAT(ITIME)+0.1
      Y=X
      RETURN
      END
```